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PREPRODUCTION PROTOTYPE PACKAGE VENTILATION KIT, SECOND STRUCTURAL AND HUMAN FACTORS TEST

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FOREWORD

The structural and human factors test of the shelter ventilator reported herein is the second of the series. The first test of the experimental prototype Package Ventilation Kit (PVK) was conducted in April 1965, and necessary structural and mechanical modifications were implemented. The motor also was tested according to the National Electrical Manufacturers (NEMA) code. Since no deficiencies were observed during the second structural and motor tests, Specification MIL-V-40645 (Army-OCD) "Package Ventilation Kit, 20-Inch Fan, Modular Drive (Civil Defense)", was issued on 16 August 1965. The pre-production prototype Package Ventilation Kit tested was developed, designed, and fabricated under Contract OCD-PS-64-22 with Mr. R. G. Hahl of the Office of Civil Defense serving as project monitor. These tests were performed under Stanford Research Institute Subcontract B-70925(4949A-28)-US with Mr. C. A. Grubb serving as project monitor.

ABSTRACT

A portable ventilation system, designed for fallout shelters, was manually operated continuously for two weeks. The Package Ventilation Kit (PVK) evaluated included a Fan Assembly plus two Drive Modules. A previous test had disclosed some mechanical weaknesses that were subsequently changed. The modified PVK functioned without any failures; therefore, Specification MIL-V-40645, "Package Ventilation Kit, 20-Inch Fan, Modular Drive (Civil Defense)", was issued 16 August 1965. Minor improvements to this specification are recommended.

Significant conclusions by the American Institutes For Research as to what can reasonably be expected in terms of a person's ability to operate the ventilator are as follows:

1. Roughly 75 per cent of the people tested, aged 14 to 48, can operate the unit for three hours at work-rest schedules of 15 minutes work--7.5 minutes rest, 20 minutes work--10 minutes rest, or 30 minutes work--15 minutes rest at effective temperatures ranging up to 82 degrees Fahrenheit. Under these same conditions, except that the maximum age of the operators was limited to 35 years, 50 per cent are able to operate the unit up to 7 hours.
2. Any inability to operate the unit will manifest itself during the first two hours of operation.
3. Approximately 99 per cent of the people tested who were in the 14 to 27 age group can operate the unit one hour without rest at effective temperatures up to 82 degrees Fahrenheit.
4. Experienced operators can be expected to operate the unit longer than inexperienced team members.
5. Sixty per cent of the males in the age range of 14 to 27 were able to operate the unit continuously for three hours at effective temperatures up to 82 degrees Fahrenheit.
6. Of the work--rest schedules tested (15 minutes work--7.5 minutes rest, 20 minutes work--10 minutes rest, and 20 minutes work--15 minutes rest), no one was significantly better than the others when operating the unit for three hours.
7. The composition of teams operating the unit should be all male whenever possible because mixed teams tend to overwork the male members, and female teams perform less efficiently.

In addition to the structural and human factors test, and prior to the release of Specification MIL-V-40645, the motor was tested to determine if the motor winding temperature rise exceeded that allowable when operated at elevations up to 5500 feet. The maximum measured termperature rise of the motor windings is 26.5°C when running at 1/3 brake horsepower. The allowable temperature rise is 56°C; therefore, this motor meets the National Electrical Manufacturers Association (NEMA) operating temperature standards when operated at ambient conditions less than 40°C (104°F). This motor also meets the Underwriters Laboratories requirements for approval.

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SECTION 1

INTRODUCTION AND SUMMARY

A second structural, mechanical, and human factors test of the Civil Defense fallout shelter Package Ventilation Kit (PVK) was conducted by the General American Research Division (GARD) of the General American Transportation Corporation (GATX) and the American Institutes For Research (AIR) at the latter's Research Shelter Management Laboratory located at Pittsburgh, Pennsylvania. The PVK can be pedal driven or can be motor driven when electrical power is available (see Figure 1). The PVK was developed, designed, and fabricated by GATX under Contract OCD-PS-64-22, Work Unit 1423A, for the Office of Civil Defense.

During the first test of the PVK (Ref. 1), which was driven by <u>three operators</u>, the principal mechanical problems were a broken chain connecting link and excessive chain sprocket wear. Based on AIR's human factors evaluation the following design changes were recommended: (1) the handle bar should be higher and wider, (2) the ability to tighten the handle bar with the thumbscrew provided should be increased, (3) the quick-adjust mechanism on the seat which was unnecessary and hazardous should be changed, and (4) the clutch in the pedal crank which is unnecessary for safe operation should be deleted.

Based upon the results of the first test, the following changes were incorporarated into the PVK for the second test:

(1) Endless-riveted chain.

(2) Hardened chain sprockets as required.

(3) Wider and higher handle bars.

(4) Larger thumbscrew with finer thread on handle bar adjustment.

(5) Conventional bicycle-type saddle height adjustment.

(6) Clutchless pedal crank.

During the second test the PVK was run continuously for two weeks, no difficulty was experienced during manual operation by two operators.

AIR provided the necessary human factors support, and their human factors evaluation is included in Supplement I. The human factors aspect of the study concerned itself with the performance of the individual operator, variable work-rest schedules, and variable team compositions (all men, all women, and mixed).

Figure 1 PACKAGE VENTILATION KIT IN OPERATION

The motor specified for the shelter ventilator was tested to determine if temperature rise of the motor windings exceeded that allowable for Class A insulation when operated at elevations up to 5500 feet. The description and results of this test are reported in Supplement II of this report.

SECTION 2

STRUCTURAL ANALYSIS

2.1 Test Description

The PVK evaluated consisted of a Fan Assembly and two Drive Modules. The ventilator was driven manually, two persons at a time, for 338 continuous hours, or for over two weeks. The PVK was pedalled at 53 rpm and the plastic ducting constricted so that 0.2 horsepower total input was required. The necessary constriction of the plastic duct was determined by measuring the air flow rate developed during the test, and by using the fan performance curves and a transmission efficiency of 94 percent (Ref. 2). These conditions of pedal speed and power input were not changed during the test.

2.2 Component Analysis

An analysis of sprocket wear, chain wear by means of elongation, bearing wear, and other components is presented in the following sections. For reference the two-module assembly, fan assembly, and module assembly drawings are presented in Figures 2, 3, and 4 respectively. Recommended modifications to the specification are included herein. Part numbers referred to are those used in the specification (see Ref. 3, section 2.2).

2.2.1 Sprockets

2.2.1.1 Motor Sprocket

The wear of the motor sprocket (Part No. 1423A-1105-2) was negligible (see Figure 5). The black oxide finish on the sprocket was worn off the load bearing face of the sprocket teeth. The outer surface of the tooth face curvature

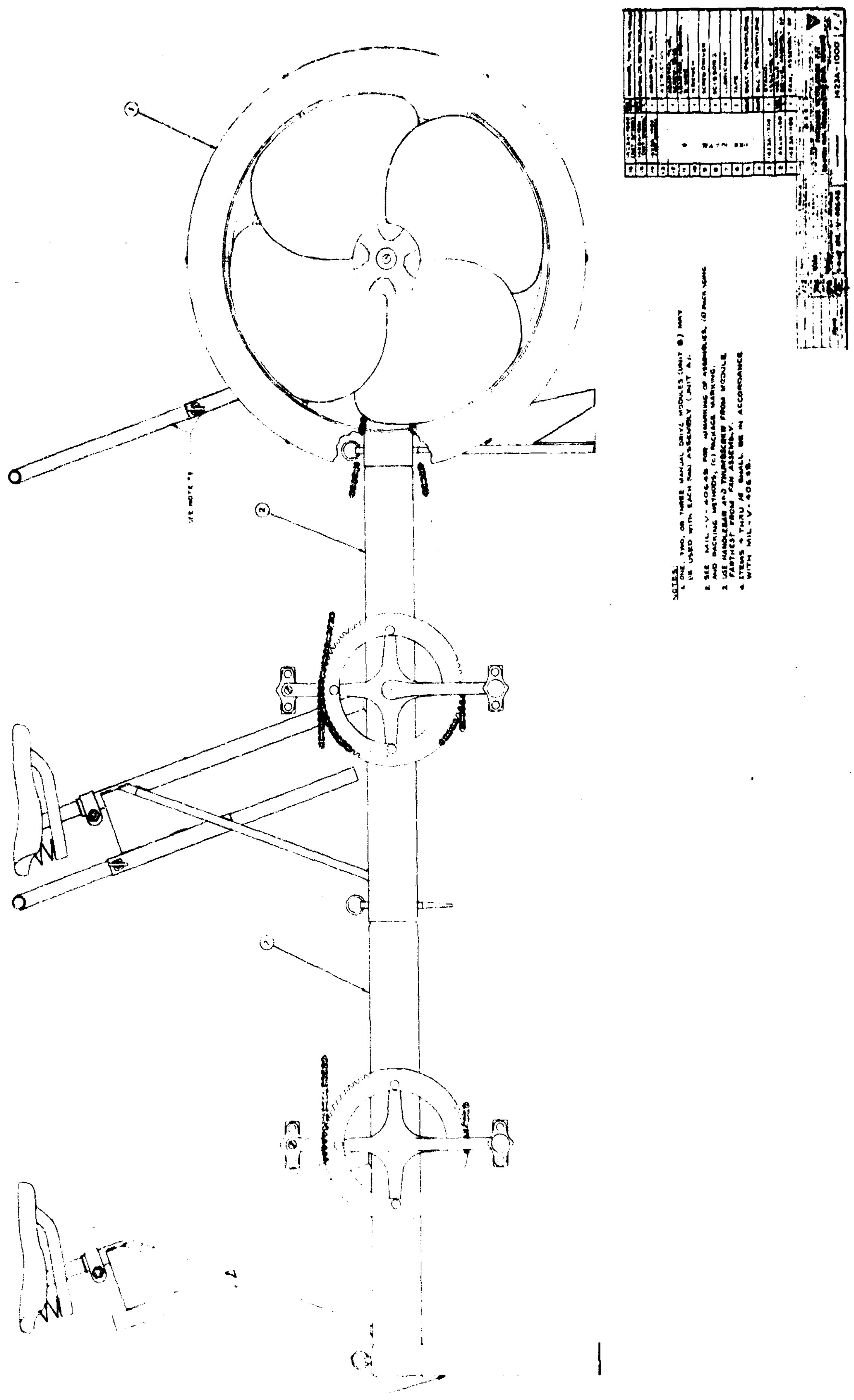


Figure 2 PACKAGE VENTILATION KIT ASSEMBLY (Part No. 1423A-1000)

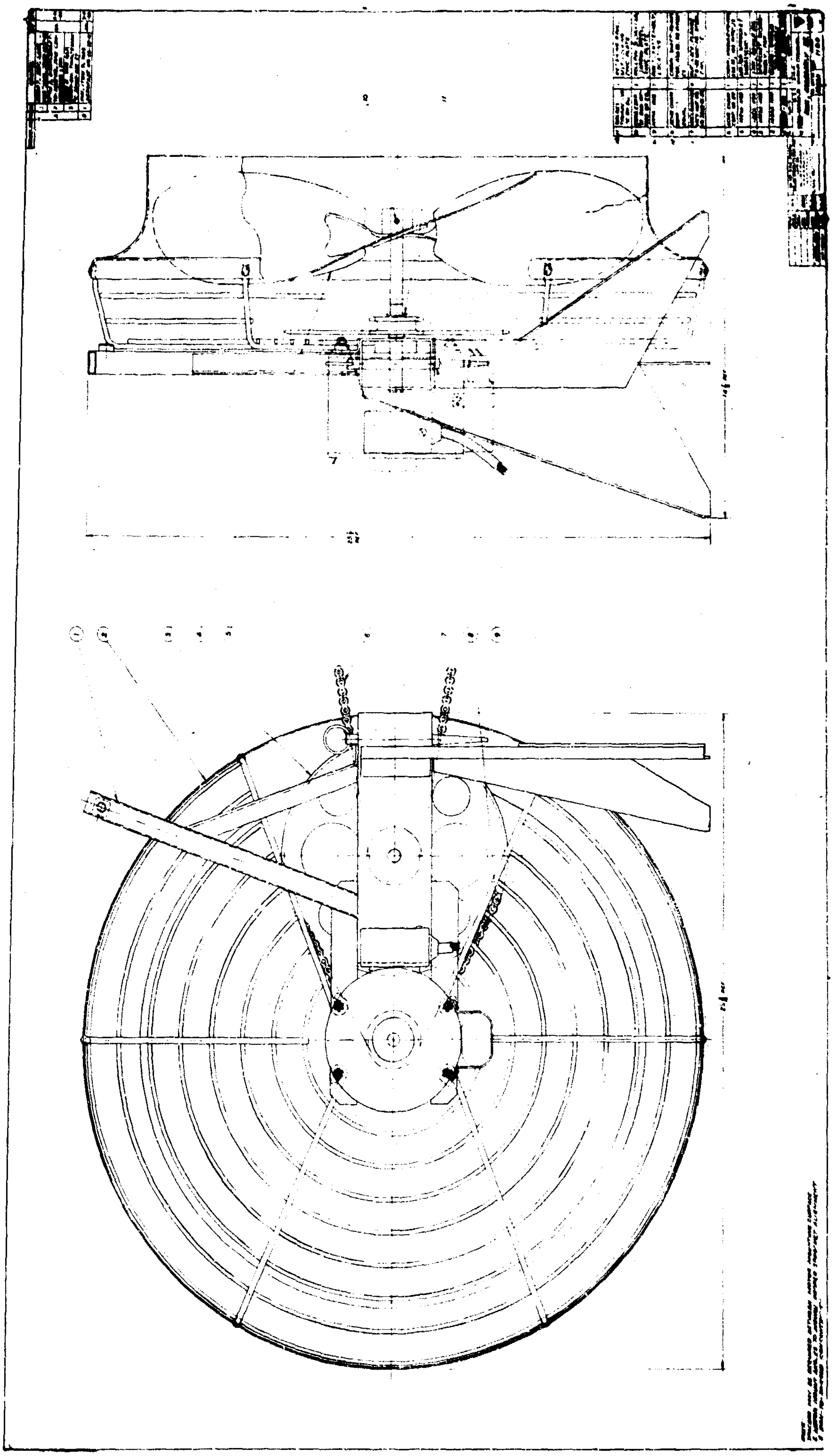


Figure 3 FAN ASSEMBLY (Part No. 1423A-1100)

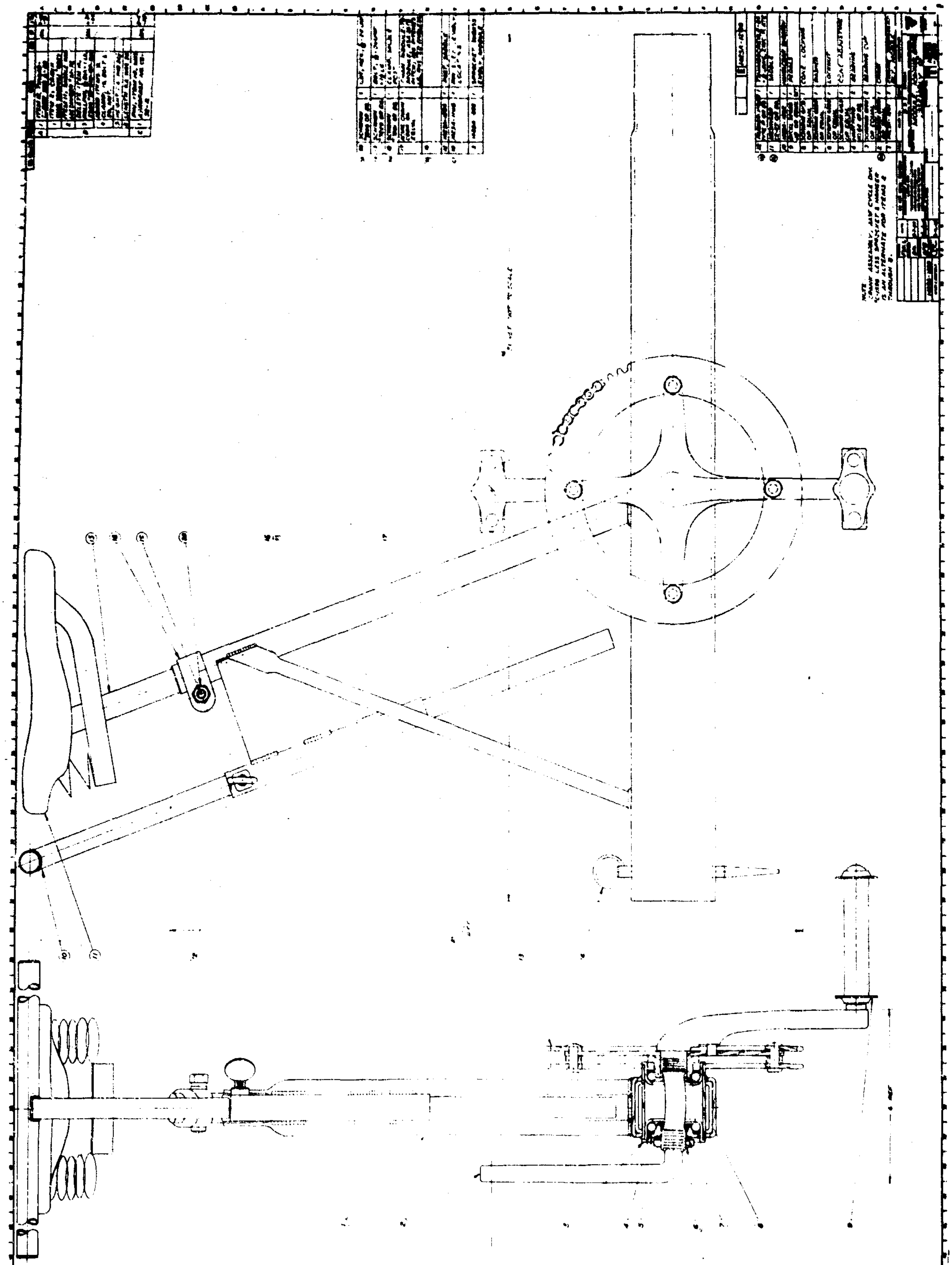
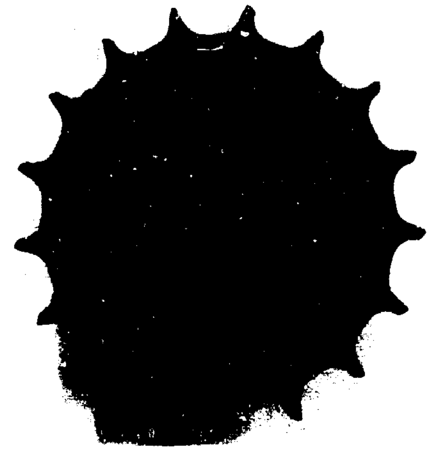


Figure 4 MODULE ASSEMBLY (Part No. 1423A-1200)

Figure 4 MODULE ASSEMBLY (Part No. 1423A-1200)

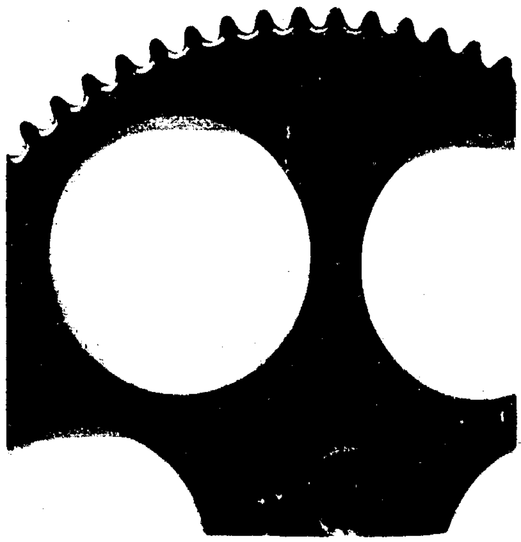
SPROCKETS AFTER FIRST TEST

IDLER SHAFT

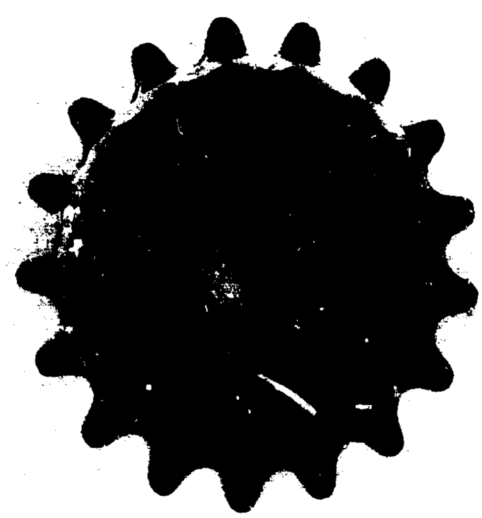


MOTOR SHAFT

SPROCKETS AFTER SECOND TEST



IDLER SHAFT



MOTOR SHAFT

Figure 5 SPROCKETS AFTER TESTS

was rounded at its intersection with the sprocket outside diameter to approximately a 1/64 inch radius on the load carrying side. The opposite side of each tooth profile intersected the outside diameter to form a sharp corner. This opposite (non-load carrying) side had the black oxide finish unharmed.

2.2.1.2 Idler-Shaft Sprockets

In the earlier test the teeth of the 17-tooth sprocket in this subassembly (Part No. 1423A-1103) was extremely worn (see Figure 5), much the same as the motor shaft sprocket. As a result of case hardening of the teeth negligible wear occurred. The only indication of wear was the absence of the black oxide finish from part of the load side of the teeth face, on the inboard flank of the sprocket, and on the outboard flank where the finish was worn off in a scalloped pattern matching the configuration of the chain. There was no indication of metal being worn from this sprocket.

The large (75-tooth) sprocket in this subassembly also showed no signs of material being worn away. Here too, only the black oxide finish had worn away in the load bearing surfaces of the teeth (see Figure 5).

2.2.1.3 Crank Sprockets

The dual sprockets (Part No. 1423A-1203-1) in this subassembly showed no wear.

2.2.2 Chain

On the fourteenth day of the test, the module-to-module chain disengaged its sprockets once, and the module-to-fan chain came-off once. In both cases this was due to improper assembly at the factory of the crank closest to the

fan. The lock washer of this assembly (Part No. 1423A-1200, Item 7) was missing; allowing the bearing adjustable cone to work loose, and the module sprockets to move axially about 1/8 of an inch. The chain disengagement is attributed to the resultant sprocket misalignment, since both disengaged chains mesh with this sprocket assembly. This chain jumping is not considered a failure, but an item for inspection under the quality assurance provisions of the specification (Ref. 3, Table I, Category 111).

Chain elongation which occurred during the test was not excessive. The chain was measured before and after the test using the fixture and height gage shown in Figure 6. As shown an 18-pound load is applied to the chain as established by the Association of Roller and Silent Chain Manufacturers. The maximum increase in length was 0.38 percent (see Table I) in the shaft-to-motor chain.

Table I

Chain Wear

Chain:	Chain Length		Elongation	
	Number of Pitches	Nominal, Inches	Inches	Percent of Original Length
Module-to-Module (Part No. 1423A-1200, Item 17)	224	84	0.138	0.16
Module-to-Fan (Part No. 1423A-1100, Item 6)	152	57	0.114	0.20
Shaft-to-Motor (Part No. 1423A-1100, Item 8)	88	33	0.126	0.38

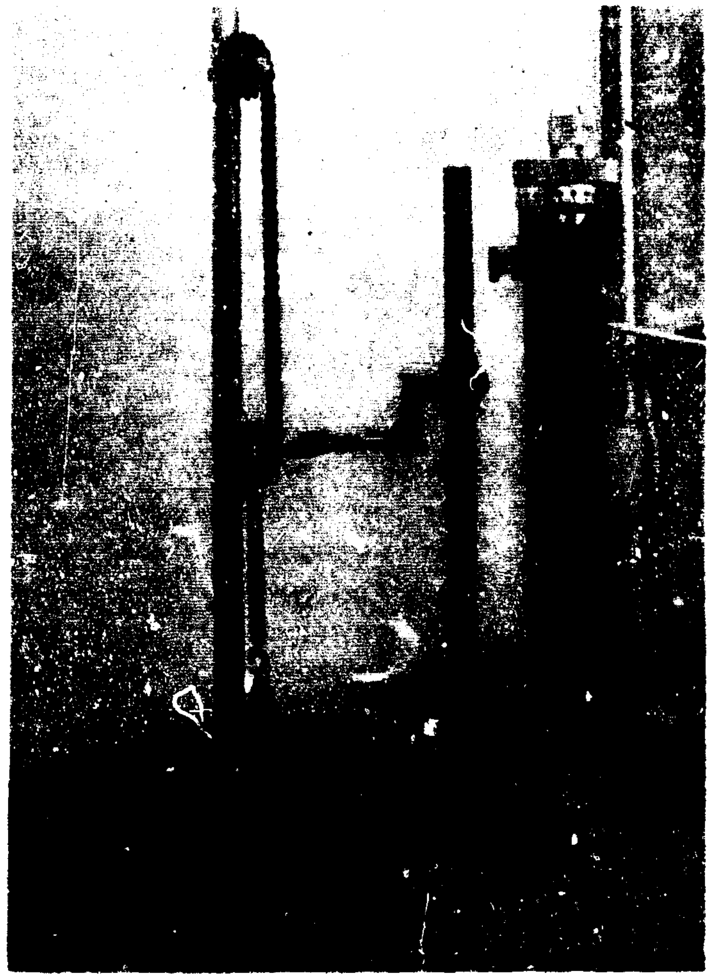


Figure 6 TECHNIQUE FOR MEASURING CHAIN WEAR

2.2.3 Bearings

2.2.3.1 Motor Bearings

No problems occurred during the test with the motor bearings. The bearing sleeve of the motor (manufactured by the Emerson Electric Manufacturing Company) is babbitt-lined, steel backed, and includes an oil saturated cellulose fibre surrounding the shaft. To assure reliability of the bearings after long periods of storage the PVK specification requires the shaft to be finished prior to assembly with solid film lubricant after surface treatment with a manganese

phosphate base. The surface treatment provides the best resistance to corrosion, and the dry-film aids in assembly, gives further corrosion protection, and decreases the bearing power losses when the unit is in operation.

2.2.3.2 Idler-Shaft Bearing

The idler-shaft (Part No. 1423A-1101-7) and the sleeve bearing (Part No. 1423A-1103-3) were measured after the test and compared to the initial dimensions (see Table II). As indicated the maximum clearance increased from 0.0028 inches to 0.0065 inches. This increase in clearance did not affect the operation of the unit.

Table II

Idler-Shaft and Bearing Wear

Measurement of:	Dimensions		Wear
	Before Test	After Test	
Bearing Bore, inches	0.4988	0.5018 max. 0.4998 min.	0.0030 max. 0.0010 min.
Shaft Diameter, inches	0.4960 min. 0.4975 max.	0.4953 min. 0.4970 max.	0.0007 max. 0.0005 min.
Clearance, inches	0.0028 max. 0.0013 min.	0.0065 max. 0.0028 min.	

2.2.3.3 Crank Bearings

The module crank bearings (Part No. 1423A-1200, Items 3, 4, 5, and 8) are ordinary bicycle components. The bearing balls show no wear, either dimensionally or in appearance. On the drawn steel outer races, or cups, in the load bearing area only the cadmium plating is worn off. On the inner races (adjusting and locking cones) the rather roughly macnined (unground)

ball contact surfaces have a band of the plating worn away, also. The machined finish, however, is unaltered as a result of the usage in this test. Prior to operation all items except the locking cone are protected from corrosion. This part (Part No.1423A-1200, Item 8) should be finished with a solid film lubricant.

2.2.4 Saddle Post

Both saddle posts (Part No. 1423A-1204) became slightly bowed due to the operator loads during the test. The extent of the bowing was approximately 3/32 to 1/8 inches at the center of this 15 inch long, 7/8 inch outside diameter tubular piece. The post was badly indented by the mast clamp (see Figure 7). Also, the top of the post was indented and scored by the pressure and movement of the saddle clamp. This deformation, while it did make moving of the member more difficult, was not so severe as to prevent changing the saddle height. The wall thickness of this member (Part No. 1423A-1204) should be increased from the bicycle manufacturers standard 16 B.W. gage (0.065 inch thick) to 14 B.W. (0.083 inch thick). This change will give the member greater resistance to bending, and compressive loads imposed by the clamps.

2.2.5 Handle Bar and Guide

The handle bars (Part No. 1423A-1202) used in both drive modules were bowed slightly, 3/8 inch maximum, in the 28-inch long upright. The handle bar used in the fan assembly did not bow. Since the slight bowing that did occur did not affect the operation of the handle bar movement no change is recommended.

The handle bar guide in the present fan assembly design (see Figure 3) extends down to the top of the fan housing spine. This method of support was

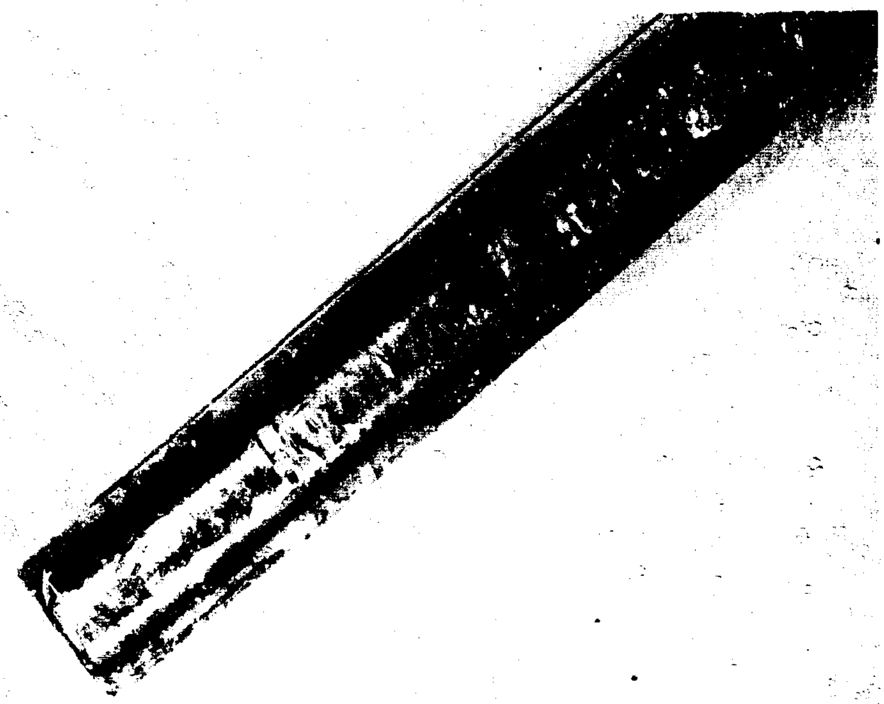


Figure 7 SADDLE POST

evaluated in the first test and was found to be suitable. A modified method of support was evaluated during this test; the handle bar guide extends to the floor and acts as another foot (see Figure 8), giving the assembly more stability. This alternate was found, in the test, to work very satisfactorily. Adoption of this guide-leg permits simplification of the fan frame subassembly by (1) deletion of the handle bar guide support (Part No. 1423A-1101-2), and (2) simplification of the stand left leg (Part No. 1423A-1101-5) by shortening the forward rib of this member. This latter method of supporting the fan is recommended for production since the stability of the unit is increased and the cost is reduced. This change will not affect the packaging.

The handle bar guide (Part No. 1423A-1101-1) and mast (Part No. 1423A-1201-5) require a hole (3/16-inch diameter minimum) at their base, or in the

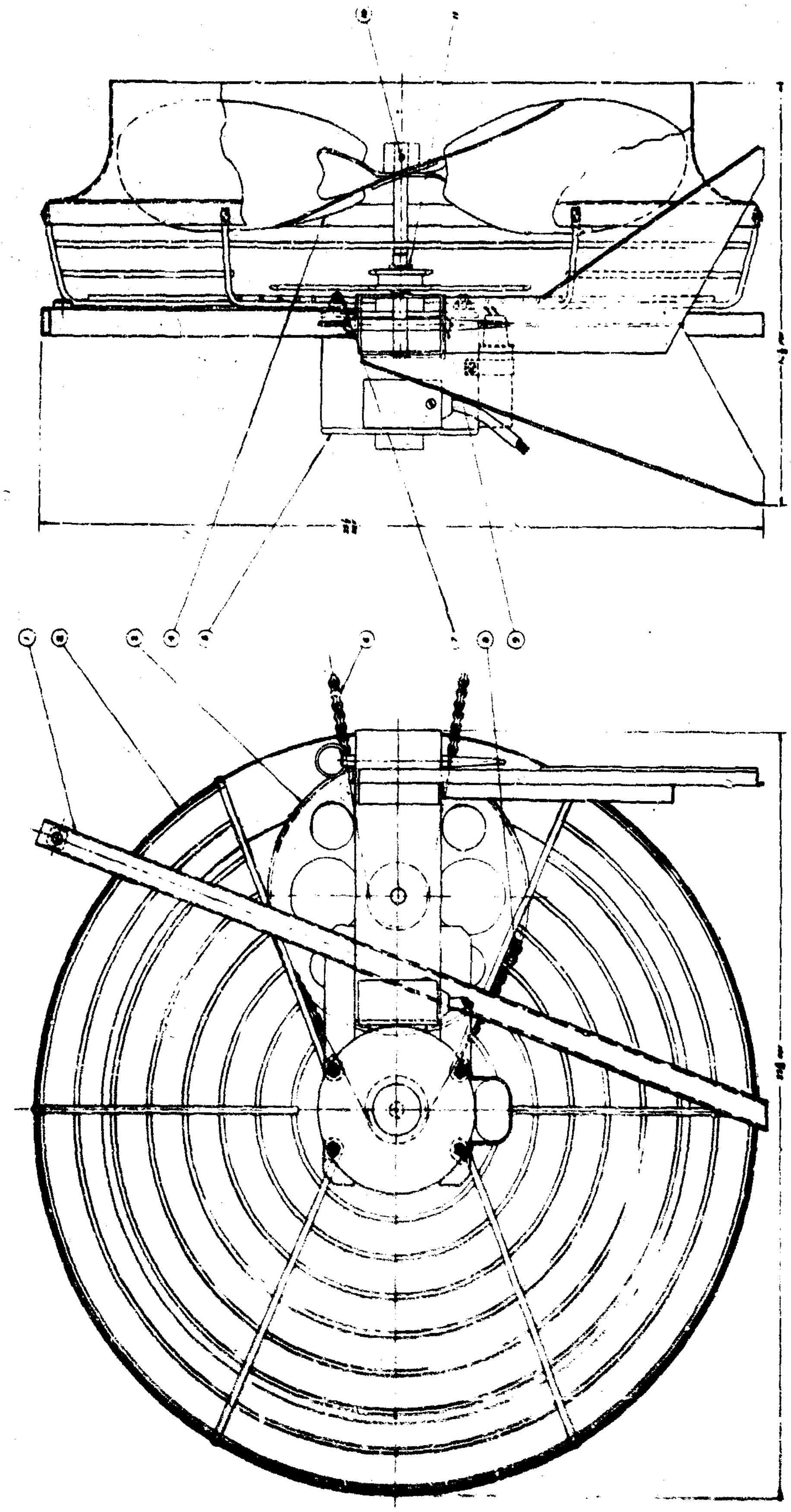


Figure 8 FAN ASSEMBLY, MODIFIED

spine (Part Nos. 1423A-1101-3 and 1423A-1201-6) at their intersection to facilitate drainage of the finishing materials. This is necessary to obtain the maximum corrosion resistance at the inside surfaces of the tubing.

2.2.6 Connecting Joint

The unit tested is assembled by joining the swaged (diminished in size) male-end at the front of the module spine with the expanded female-end at the rear of the module or fan assembly spines (see Figure 9). A close fit of the mating surfaces -- 0.015-inch maximum male-to-female clearance -- was obtained by cold forming the rectangular spine tubing with production tooling. This unit was very rigid (as rigid as the stand-by flange-type, see Figure 10). Consequently the swaged-expanded joint is recommended for production.

Figure 9 SWAGED-EXPANDED CONNECTING JOINT

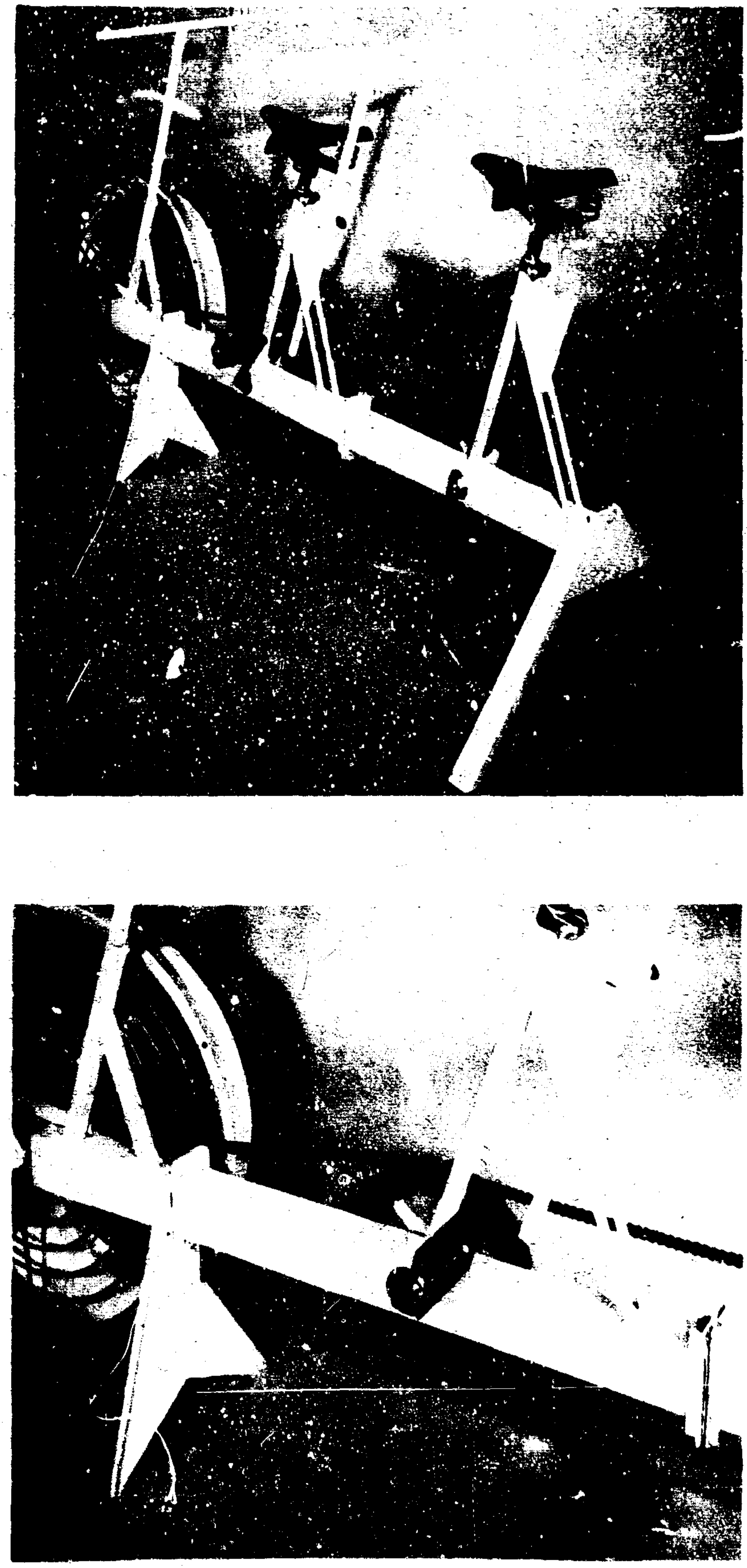


Figure 10 FLANGE-TYPE UNIT

2.2.7 Locating Pin

Long tapered locating pins (Part No. 1423A-1106) were used in this test, replacing the spring-loaded ball-lock pins previously used. It has been found that the increased length of the taper and increased over-all length of the pin has facilitated assembly of the unit. This pin is recommended for production.

2.2.8 Pedals

As the test progressed, it was observed that the pedals did not spin as freely as new pedals, indicating that the bearing surfaces were wearing. The disassembled shaft from one of the pedals is pictured in Figure 11. The bearing surface near the threaded end is worn, forming a groove whose diameter is approximately 0.025 inches smaller than the unworn portion of the shaft. The outboard bearing surface of the shaft is worn so slightly that the wear is unmeasurable. Due to this rather heavy wear, it is recommended that ball-bearing pedals be specified (Part No. 1423A-1200, Item 9: Excel No. B2660UB). Further, the shaft of the pedal should be dry-filmed and the bearings lubricated as specified for the crank bearings (Ref. 3, paragraph 3.8).

Figure 11 ILLUSTRATION OF PEDAL WEAR

All pedals were tightened with the wrench provided at the beginning of the test (see Figure 12); however, on the second day of the test the right pedal on the module closest to the fan fell off at the crank. The loosened pedal was observed at least an hour before it fell-off; but the operators failed to tighten it with the wrench furnished. Nevertheless, the pedal and crank threads were stripped. Both items were replaced and the test continued. No other pedals came loose during the test. This malfunction could have been avoided if the operator or observer used good judgment. This malfunction, therefore, is not considered a failure.

The pedals and crank, which are standard bicycle parts, have right-hand thread on the right side, left-hand thread on the left. To eliminate difficulty in assembly and to avoid stripping of threads, it is recommended that all crank and pedals have right-hand threads.

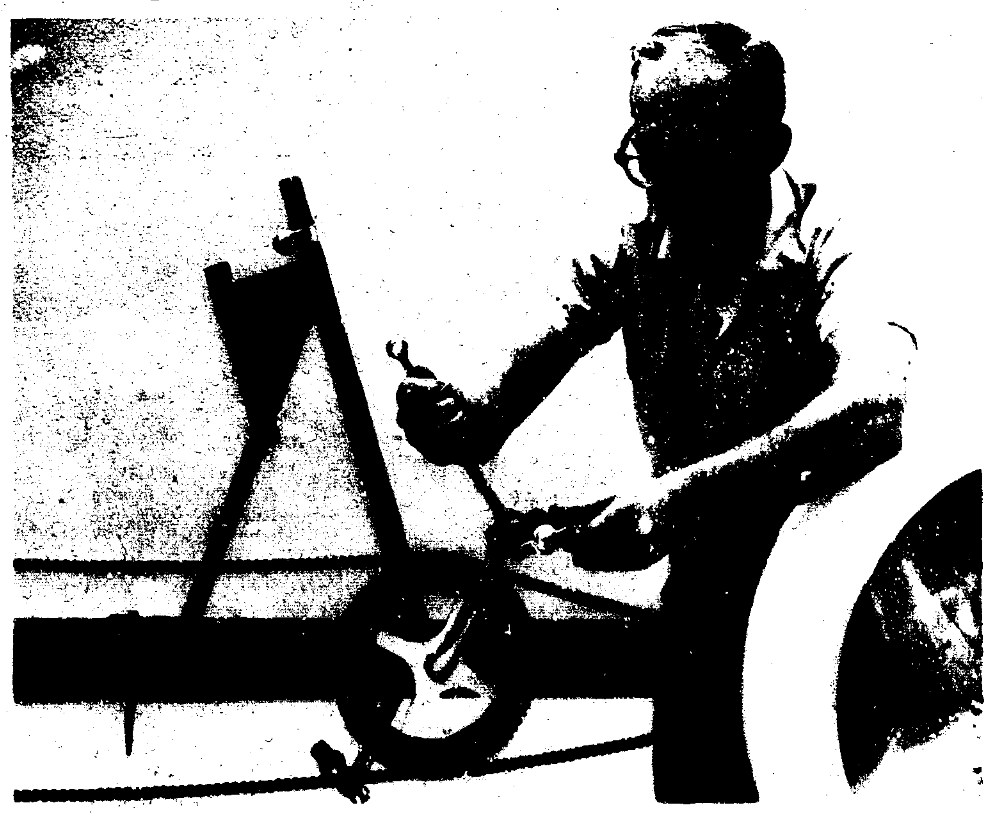


Figure 12 TIGHTENING PVK PEDAL

2.2.9 Motor Mounting

No difficulty with the motor was observed during the first test. The motor was mounted with through-bolts; thus the core, end-bell opposite the drive shaft, and rotor did not overhang the mounting brackets. In preparing for this test it was noticed that pedaling the unit became difficult at high speeds. The resistance to pedaling was accompanied by a noise that sounded like a scraping or an interference of parts. This motor was not mounted with through-bolts, but with separate bolts to the shaft-end end-bell. The chain load applied to the motor shaft caused the motor housing to distort. The resulting misalignment of the motor sprocket to the idler shaft, and the misalignment of the motor bearings caused a high resistance to pedaling. The specification thus calls for the mounting of the motor with through-bolts.

2.2.10 Finishes

It has been observed during the test that either zinc or cadmium plated rivets and rollpins have rusted where hit with a hammer and punch in assembly; therefore, it is recommended that Part Nos. 1423A-1100, Item 10; 1423A-1100, Item 11; 1423A-1102, Item 3; 1423A-1105, Item 3; 1423A-1200, Item 12; and 1423A-1203, Item 2 be finished with a solid film lubricant as specified in paragraph 3.9 of MIL-V-40645. These parts are all small and can be tumble-finished in bulk quantities. Solid filming the rollpins will aid in assembly and assure greater resistance to corrosion.

SECTION 3

RECOMMENDATIONS

The following modifications to the Specification MIL-V-40645 are recommended:

1. Cone, Locking -- Part No. 1423A-1200, Item 8 -- Finish: Solid film lubricant (see 3.9 of MIL-V-40645).

2. Post, Saddle -- Part No. 1423A-1204 -- increase tubing wall thickness to 0.083 inches from 0.065 inches.

3. Guide, Handle Bar, Fan -- Part No. 1423A-1101-1 -- Modify as shown in Figure 8, page 15 of this report.

   Support, Handle Bar Guide -- Part No. 1423A-1101-2 -- Delete.

   Spine, Fan -- Part No. 1423A-1101-3 -- Add holes for Part No. 1423A-1101-1.

   Leg, Left, Fan -- Part No. 1423A-1101-5 -- Modify as required. See Section 2.2.5.

4. Spine, Fan -- Part No. 1423A-1101-3 and Spine, Module -- Part No. 1423A-1201-6 -- Add 3/16 inch diameter minimum holes at the intersection of handle bar guide or mast and the spines to facilitate finishing material drainage. (If Recommendation No. 3 is adopted, the 3/16-inch diameter hole is not required in the Spine, Fan.)

5. Pedals -- Part No. 1423A-1200, Item 9 -- Change to Excel B2660UB (ball-bearings) from Excel S2660UB (sleeve bearings). Add: Shaft Finish, Solid film lubricant (see 3.9 of MIL-V-40645). Add: Bearing grease, same as specified for crank bearings (see 3.8 of MIL-V-40645).

6. Crank -- Part No. 1423A-1200, Item 2 -- Holes shall have right-hand thread only.

   Pedals -- Part No. 1423A-1200, Item 9 -- All pedals shall have right-hand thread only.

7. Part Nos. 1423A-1100, Item 10;

   1423A-1100, Item 11;

   1423A-1102, Item 3;

   1423A-1105, Item 3;

   1423A-1200, Item 12;

   1423A-1203, Item 2.

   Finish: Solid film lubricant (see 3.9 of MIL-V-40645).

All other recommendations in this report have already been included in the specification.

In application of the PVK, problems in control of air patterns within shelters will develop. To diminish these problems a blacksmith's hand hammer or a single bit axe should be included in the Civil Defense Package Ventilation Kit to break holes in shelter interior partitions.

Based on GARD's experiences when performing the duct tests (Ref. 5) and the evaluations performed on the PVK at the American Institutes For Research under Contract OCD-PS-66-9, OCD Work Unit 1522A, the following changes to Specification MIL-V-40645 are recommended:

1. Elbow -- The smooth 40-inch radius plastic elbow must be cut at 75-degrees when uninflated so that the resulting inflated elbow is 90-degrees, it is recommended that "Figure 6 of MIL-V-40645" be

modified as shown in Figure 13. The cuffs have been removed since they are of no value for taping the tubing to the elbow, and in most cases produce wrinkles and distortion. Since polyvinyl chloride material is easily heat sealed it is recommended that this material be included in paragraph 3.7.3 of MIL-V-40645; therefore, the second sentence of this paragraph should read as follows:

> "The elbow shall be fabricated from 4-mil thick polyvinyl chloride or type II, grade C, finish 1 polyethylene conforming to Federal Specification L-P-378 with a minimum flat dimension of 31 inches."

2. Handle Bar -- The color of the handle bar (Part No. 1423A-1202) should be changed to anything but white, or solid dry-filmed (black). The white handle bar is hidden in the white polystyrene package, and is somewhat difficult to find.

3. Saddle Post -- The length of the saddle post (Part No. 1423A-1204) should be increased from 15 inches to 18 inches. This is necessary so that the saddle post can be grasped after its insertion in the mast.

4. Pedals -- No markings, other than "L" or "R" shall be put on the pedals (Part No. 1423A-1200, Item 9), including trademarks and the name of the manufacturer. "XL" stamped on both of the Excel pedals caused considerable difficulty when assembling the pedals to the crank.

5. Marking -- Intermediate Box No. 1 (see Figure 11 of MIL-V-40645) shall be marked "OPEN THIS END" on the end which contains the tools and accessories. This change would be reflected in 5.1.3.1 of MIL-V-40645. Finding the tools appears to be somewhat difficult.

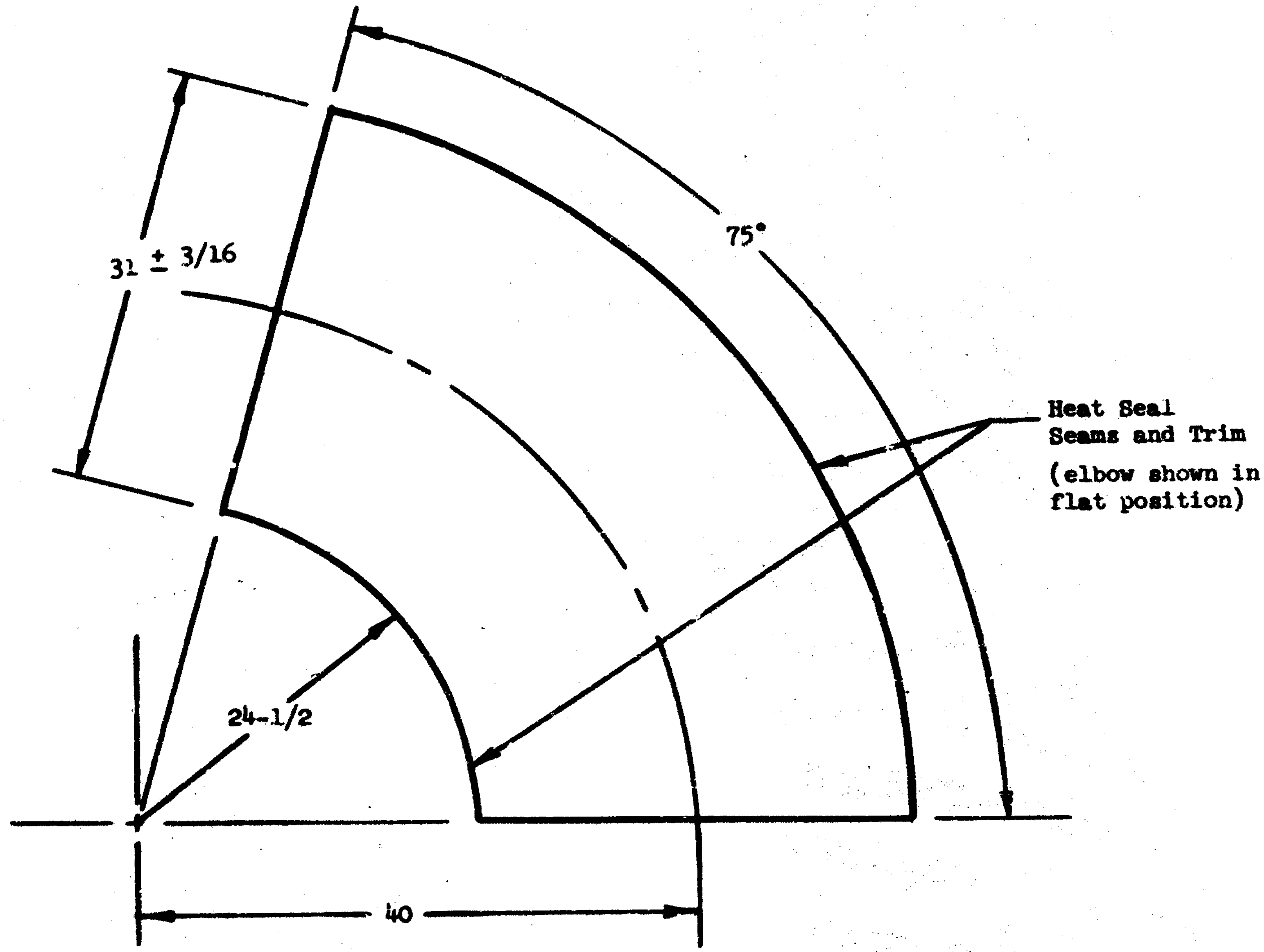


Figure 13 PVK FLEXIBLE PLASTIC ELBOW

6. Scissors -- The scissors should be attached to the exterior fan assembly box. This is necessary so that a tool is available for cutting the nylon or polypropylene strapping.

7. Tape -- The tape used in all of GARD's shelter tests adhered to any surface encountered, clean or dirty, while the specified 3M tape adheres very poorly to masonry surfaces. Based on 1-1/2 inch wide tape a savings of at least $1.70 per Kit will be realized. Delete from paragraph 3.7.4 of MIL-V-40645 the second sentence (The tape shall conform to Specification PPP-T-66), and add the following to this paragraph:

> The tape shall be cloth with a non-hygroscopic vinyl plastic coating and a pressure-sensitive rubber base adhesive.

Also add the following new paragraph:

> 4.9 Tape. The tape shall be equal to or interchangeable with Arno Adhesive Tapes, Inc. Type C-511.

SUPPLEMENT I

EVALUATION OF PREPRODUCTION PROTOTYPE
PACKAGE VENTILATION KIT:
SECOND HUMAN FACTORS TEST

Prepared by:

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AMERICAN INSTITUTES FOR RESEARCH

AIR Report E82-8/65-FR

August 1965

Prepared for:

GENERAL AMERICAN RESEARCH DIVISION
General American Transportation Corporation

INTRODUCTION

In late March and early April, 1965, the American Institutes For Research conducted an evaluation of a Package Ventilation Kit (PVK) manufactured by the General American Research Division (GARD) of the General American Transportation Corporation, 7449 North Natchez Avenue, Niles, Illinois (Ref. 1). The following report describes the evaluation of a modified model of the PVK conducted during August of 1965. This unit was fabricated according to MIL-V-40645 (Army-OCD), "Package Ventilation Kit, 20-Inch Fan, Modular Drive (Civil Defense)", 16 August 1965.

Description of the Apparatus

The machine can be technically described as a portable, pedal-powered emergency shelter ventilation kit. The version tested consisted of one fan unit designed to be powered by an electric motor or a mechanical drive, and two interchangeable drive modules, each equipped with an adjustable seat and handle bar, and bicycle-type pedals, crank, and sprocket. The fan and modules were mounted in tandem, and American Standard Association (ASA) No. 35 chain connected module-to-module and the forward-most module to the fan. The PVK, as tested, is shown in Figure 14.

Four major changes were instituted in the modified PVK used in the present evaluation. These changes are listed below accompanied by the reasons for which they were made.

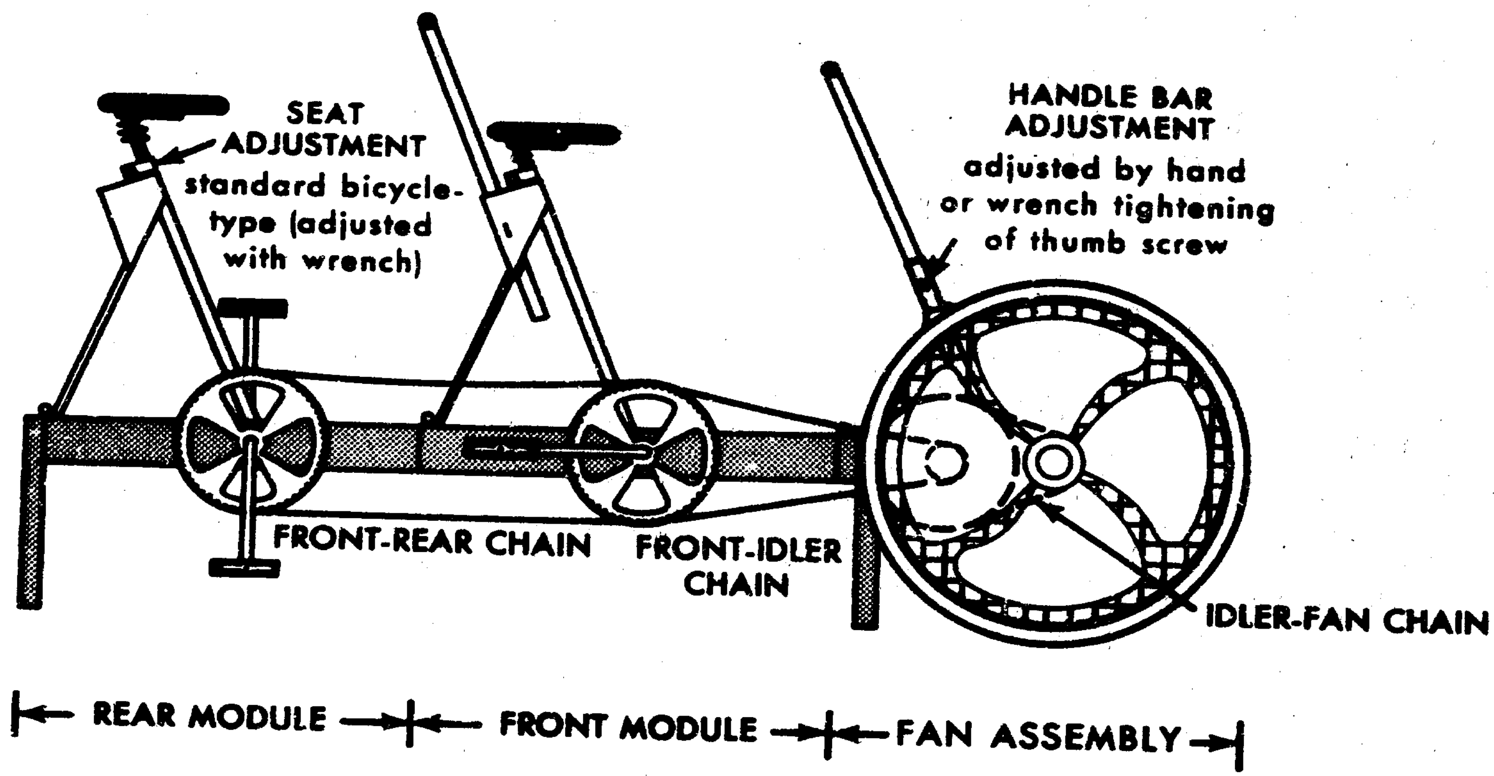

Figure 14 TWO-MODULE PACKAGE VENTILATION KIT (revised)

1. Case-hardened 17-tooth sprockets. High sprocket wear was the major mechanical shortcoming of the first PVK, causing serious operating difficulties to occur during the last six hours of the evaluation (Ref. 4, p. 23).

2. Longer, wider handle bars and an improved fan assembly handle bar support. In addition, the handle bar supports, especially the one on the fan assembly, were difficult to tighten sufficiently to keep the bar from telescoping into the support. (Ref. 4, p. 28).

3. The elimination of clutches from the module crank assembly. The clutches on the earlier unit were found to be unnecessary for the safe operation of the machine (Ref. 4, p. 29).

4. The elimination of the quick-adjust mechanism on the seat. This device was found to cause injury to the fingers of some operators as well as not being useful enough to justify its cost (Ref. 4, p. 27).

5. Swaged and expanded mating ends of the module and fan frames. Side-to-side wobble was observed during the first test. (Ref. 4, p. 25).

The first PVK tested consisted of three modules in series with the fan. The use of only two modules in the present evaluation represents the only other major change in the apparatus from the last evaluation. The purpose of this change was to test the two-operator PVK, as it is this configuration which will most likely be stocked in shelters.

Outline of the Evaluation

The present evaluation had as its goals: (1) the continuous operation of the revised model of the PVK for 14 days (336 hours) and, (2) the further evaluation of operator limits. The first goal reflected OCD's desire to

demonstrate the machine's ability to withstand the strain imposed by two weeks of continuous operation: the projected maximum fallout shelter stay. The second goal represented the need to learn more about the performance limits of operators as operating team composition, length of operation without rest, and effective temperature vary.

1. Mechanical Considerations. Members of GARD's engineering staff were on hand at all times during the evaluation to observe the machine's mechanical functioning. In addition, AIR's observation personnel were instructed to maintain a close watch over the machine, and to record malfunctions or developing mechanical problems as they become noticeable. AIR's observations are reported herein.

2. Operator Limits. The evaluation of the operator limits was designed to probe the subject teams' operating efficiency when exposed to different work-rest intervals, team compositions, and working shift lengths. To this end, three substudies were run as summarized in Table III on p. 33.

a. Regular Shifts. The first week of the test was used for Regular Shifts, i.e., the varying of work-rest intervals in operating shifts of three-hours duration. Subjects, working in three-person teams of various composition (see below), operated one shift on each of three consecutive days, using a different work-rest schedule each day. The three schedules were as follows:

Schedule	Work (minutes)	Rest (minutes)
1	15	7.5
2	20	10
3	30	15

Team composition included the four possible combinations of male and female subjects:

Composition	Males	Females
A	3	--
B	2	1
C	1	2
D	--	3

b. Endurance Shifts. During the second week of the study, teams representing all of the above team compositions operated the apparatus for nine-hour Endurance Shifts.

Only one Endurance Shift was attempted per day: The first four days were performed by Compositions A through D, working under Schedule 3; the final two days tested Compositions A and D on Schedule 1. Schedule 3 was chosen for the initial days because, on the basis of an informal survey among subjects operating Regular Shifts, it was though the easiest to operate. Schedule 1 was chosen for the last runs because it was thought the most difficult. Both of these informal judgments were later born out in the responses from the telephone questionnaire (see Table VI, p. 44). Subjects were recruited at random from the file of applicants and assigned to a schedule and composition combination. The major selecting factor for subject participation in these Endurance Shifts was that the subject had not operated previously in this evaluation.

c. No-Rest Shifts. The promising results obtained in the Endurance runs prompted an attempt to determine the limits of no-rest operation. This test of operator limits involved permitting subjects to perform a full, three-hour shift without rest. The three possible combinations of two riders were used: two males (Composition E), one male, one female (Composition F), and two females (Composition G). Each composition included two teams with, and two without, previous experience operating the

machine. Three-person teams were scheduled for every No-Rest Shift, but one member was required to wait as a standby. If either starting rider was removed from the machine, the standby would take his place and continue the no-rest operation. Where possible, the relieved rider would himself stand by to relieve. If he could not, a fresh replacement was provided.

Those hours not part of the three substudies can be divided into three-hour Open Shifts. These Open Shifts, so called because they were not to be a part of the operator evaluation, were performed by three groups of four or more subjects with each group assigned to the same shift for thirteen days in succession. The shifts operated by these groups were: the midnight to 3:00 A.M., the 3:00 A.M. to 6:00 A.M., and the 6:00 A.M. to 9:00 A.M. The major purpose for such an arrangement was to provide a dependable source of operators for the late night hours. Dependability was assured by making the group as a whole responsible for having some three of its members always on hand to operate the assigned shift. The membership of one group was male; the second, female; and the third was mixed.

The same three-person team from each group operated the PVK during the first three nights, thus permitting the data gathered from each team to be included as Regular Shift cases. In a second instance, group teams, by being permitted on three shifts to choose their own work-rest schedule, also provided further data on work-rest schedule perference. Group teams, then, were more valuable from the standpoint of the evaluation than had they been used merely as "fill-ins," but it should be noted that, with the above two exceptions, no attempt was made to systematically evaluate their performance. These groups operated a total of 84 hours on Open Shifts, not counting the hours they spent in Regular Shift operation.

In order to completely account for the final total of 338 hours, it should be mentioned that, due to scheduling difficulties, four daytime shifts were also run as Open Shifts and, therefore, not included in the operator evaluation.

Table III

SUMMARY OF THE THREE SUBSTUDIES OF OPERATOR LIMITS AND OPEN SHIFTS

Substudy I: Regular Shift (3-Hour Duration) Operating Work-Rest Schedules

Team Composition	Schedule 1 (15 minutes work, 7.5 minutes rest)	Schedule 2 (20 minutes work, 10 minutes rest)	Schedule 3 (30 minutes work, 15 minutes rest)	Total
Composition A (3 Males)	2/6[1]	2/6	2/6	2/18
Composition B (2 Males, 1 Female)	2/6	2/6	2/6	2/18
Composition C (1 Male, 2 Females)	3/9	3/9	3/9	3/27
Composition D (3 Females)	4/12	4/12	4/12	4/36
Incomplete Cases	6/18	6/18	6/18	6/54

Substudy II: Endurance Shift (9-Hour Duration) Operating Work-Rest Schedules

Team Composition	Schedule 1	Schedule 2	Schedule 3	Total
Composition A (3 Males)	1/9	---	1/9	2/18
Composition B (2 Males, 1 Female)	---	---	1/9	1/9
Composition C (1 Male, 2 Females)	---	---	1/9	1/9
Composition D (3 Females)	1/9	---	1/9	2/18
Incomplete Cases	---	---	---	0/0

Substudy III: No-Rest Shifts (3-Hour Duration) Continuous, No-Rest Operation

Team Composition	Experienced Riders	Inexperienced Riders	Total
Composition E (2 Males)	3/9	2/6	5/15
Composition F (1 Male, 1 Female)	1/3	2/6	3/9
Composition G (2 Females)	2/6	1/3	3/9
Incomplete Cases	---	1/3	1/3

Open Shifts (3-Hour Duration) Not Part of Operator Evaluation

Description	Total
Night Operation (Midnight to 9:00 A.M.)	3/84[2]
Day Operation (9:00 A.M. to Midnight)	4/11
OVER-ALL TOTAL	42/338

[1] Number of teams which operated/number of hours operated.

[2] Number of groups which operated (see text)/number of hours operated.

METHOD

Testing Area

The evaluation of the Package Ventilation Kit took place in the Institutes' Shelter Research Laboratory. A diagram of the testing area is shown in Figure 15. The main room, in which the operation of the unit actually took place, measured 20 feet by 11 feet and had a 14-foot ceiling. It was here that all subject observation took place. Tables were placed along two walls for storage of forms and equipment, and chairs were set around for the observer, the resting subject, and others authorized to be present. Two sets of double doors, usually open, exposed the main room to unrestricted natural ventilation and maintained the room at the prevailing outdoor temperature.

The duct leading from the fan ended in the closed interior of the building. It was here that air flow measurements were taken. As in the earlier evaluation, 25 feet of duct was used, and again, the variable constriction of the duct was used to adjust the input load required of the operators at a given speed. Once adjusted during the second day of the run, the input load remained constant at approximately 0.1 horsepower per operator at 55 rpm of the pedal crank. An electric tachometer measuring fan rpm was placed in sight of the operators and the observer. The operators were instructed to maintain speed by keeping the pointer at a preset red line on the dial face.

Subject Recruitment

Subjects for the evaluation were derived from two main sources: (1) AIR staff members, their friends, and families; and (2) persons recruited from the previous evaluation. Word-of-mouth advertising from the first study provided an overabundance of candidates from which the subjects were selected.

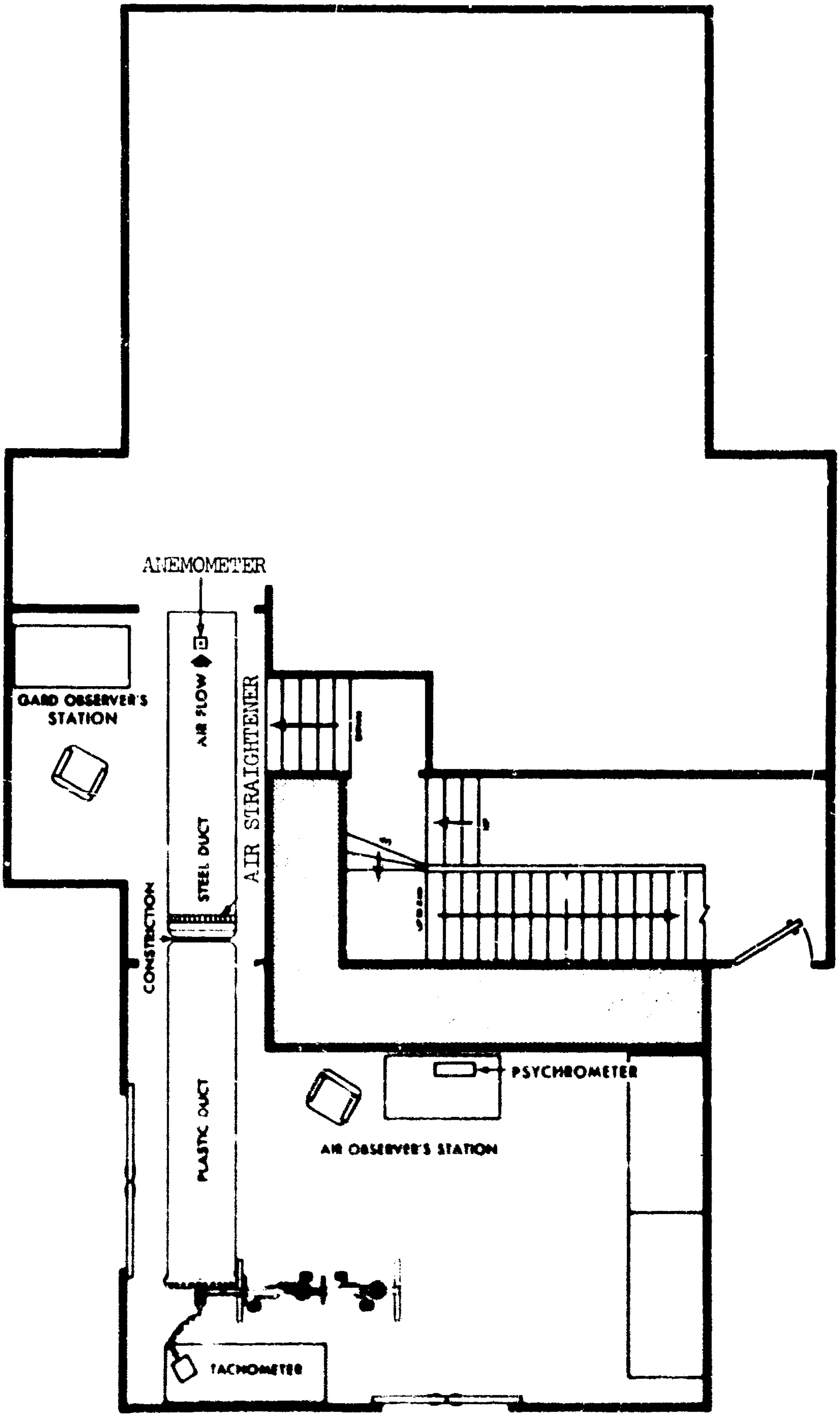

Figure [illegible]. Set-Up: Plan View

This admittedly rough measure was possible only because of the limited types of occupation and exercise found in the subject population. In prototype form it is not completely free of experimenter bias, since a good deal of estimating was required in the absence of precisely defined parameters. The Occupation-Exercise Scale, however, does provide a reasonably good estimate of how much activity the subject was accustomed to performing in the time immediately preceding his operation of the ventilation kit. The range, mode, median, and mean O-E Scale values for each shift type and for the study as a whole (broken down in terms of males and females removed) are found in Table V. It is evident from the table that the distribution of subjects was fairly normal for all substudies with the majority of subjects in each case falling on the central values of the scale.

Table V

OCCUPATION-EXERCISE SCALE INFORMATION OF SUBTEST SUBJECTS AND SUBJECTS REMOVED FROM THE APPARATUS

Category		Range	Mode	Median	Mean	Subjects
Regular Shift		1-11	4,6	5	5.2	64
Endurance Shift		3-10	4,6	6	6.0	30
No-Rest Shift		1- 9	4	4	4.6	30
Subjects Removed (All Shifts Combined)		2- 8	6	6	4.9	17
Total All Subjects:	Males	1-11	6	6	5.7	49
	Females	1- 9	4	4	4.8	52

Operational Routine

Subjects received identical treatment in regard to the routine operating procedures, regardless of which type of shift they were performing. Persons were asked to report to the testing area fifteen minutes prior to the scheduled

beginning of their shift. Base-line pulse and blood pressure measures were then taken from each. Each person was normally given a numbered vest to wear for the purposes of identification.

Shifts (excluding Endurance Shifts) changed at three-hour intervals beginning at midnight. The change was accomplished simply by having two members of the new shift, at a signal (a buzzer), trade places with the two operating members of the old shift. The remaining member of the new shift rested until the end of the first segment, and then relieved the rider on the rear module (farthest from the fan). This rider, at the end of the next segment, relieved the rider on the front module, and so on. The length of a segment is equal to the length of the rest period used on that shift; that is, a Schedule 3 shift would have 15-minute segments, etc. The usefulness of the concept of segment is that, during any segment, the operating composition remains the same.

In order to understand the evaluation of Regular Shift data, it is necessary to know what is meant by the term, "completed case". As used in this evaluation, the term stands for those cases in which a team composed of the same three riders operates the PVK one shift per day for three consecutive days, using a different work-rest schedule each day. The usefulness of the completed case lies in the fact that only when the same three persons operate the different work-rest schedules can the differences, if any, existing among the schedules be isolated.

Monitoring of operators remained essentially the same as the previous evaluation (Ref. 4, p. 22) except that the operator's blood pressure was taken at the beginning of his rest period instead of while still operating in order to increase the reliability of this measure. The No-Rest Shift, of course, required the recording of blood pressure with the subject at work on the machine.

Subject blood pressure and pulse rate were recorded throughout the entire evaluation. Each subject took his own pulse at the beginning and end of his rest period. The standard sphygmomanometer was used to measure blood pressure. Riders were removed from the machine for any of the following indications:

1. Working pulse rate in excess of 140 beats a minute.

2. Systolic blood pressure in excess of 160.

3. Diastolic blood pressure in excess of 90 if there was not a compensatory increase in pulse rate.

Water and civil defense shelter crackers were the only nutrients permitted while on shift. In this evaluation, water was available on demand, but crackers were not offered until the final half hour of the shift. Consumption of both was recorded. In addition, salt tablets were on hand and were administered on demand.

Observation Technique

A team of eleven AIR employees kept continuous watch over the evaluation. Observers were expected to stay alert to the over-all test situation, but were required to record the following specific information:

1. Adjustments made to the machine (seat, handle bars, etc.) by either the staff or the subjects themselves.

2. Blood pressure and pulse taken both before the subjects go on shift and during each subject's rest period.

3. Complaints made by the subjects concerning the machine or the test situation.

4. Food and water consumption of the subjects while on shift.

5. Lag time, or per cent of time per segment that the operators performed below the set speed, as indicated by tachometer.

6. Overspeed time, or per cent of time per segment that the operators performed above the set speed, as indicated by tachometer.

7. Stop time, or the length of time in seconds taken to change riders between shift segments, and to change teams between shifts.

8. <u>Testing room temperature readings</u>, wet- and dry-bulb, taken once an hour.

A copy of the written instructions given to each observer is included in Appendix B.

<u>Telephone Questionnaire</u>

A telephone questionnaire was administered to all subjects the week following the end of the evaluation. Subjects were questioned with regard to their occupations and pastimes in addition to being given the opportunity to express a preference for work-rest interval and to indicate complaints. Subjects were also asked to describe any body soreness or illness resulting from operation of the bike and to estimate how long they could have continued to operate. The form used for recording telephone information is included in Appendix A.

RESULTS AND DISCUSSION

Mechanical Considerations

The most important, single concern of the evaluation was to determine if the PVK, fabricated per MIL-V-40645, could successfully operate for 336 hours. The evaluation proved that the present version of the PVK can operate adequately in all respects.

In the March-April run, it was found that a worn sprocket and loose chains caused severe reduction in the ability of the machine to function properly. Faulty handle bar and seat adjustment mechanisms caused further operating difficulty. In addition, it was found that the clutch on the pedal sprocket was not necessary for the safe operation of the apparatus. The PVK in the present evaluation was modified to eliminate the mechanical problems and, in addition, the new machine was fitted with a clutchless pedal crank.

From the over-all observation of the modified PVK, it was noted that:

1. Sprocket wear was slight; certainly insufficient to cause chain slippage such as occurred in the first run.
2. The attachment of the handle bars, especially the bar fixed to the fan assembly, was much improved. Although the bars were adjustable, fewer than six per cent of the riders complained of their height or attempted to adjust them.
3. The standard, bicycle-type seat adjustment caused no great difficulty, and certainly caused no pinched fingers, as did the earlier mechanism. The fear that difficulty with such a mechanism would arise because it did not allow the seat to be easily adjusted proved groundless. In line with our findings from the first

study, only 14 per cent of the riders complained of the seat adjustment and still fewer made any attempt to readjust it, even though a wrench was provided for this purpose.

4. The clutchless pedal crank proved quite adequate. At no time during the run did it cause injury to the operators.

The results of the telephone questionnaire, Table VI, show some of the subjects' reactions to the PVK. Item six of the questionnaire asked them what they didn't like about the machine and, as shown, six categories of complaints resulted. Of these six categories, it is evident that only the seat was complained of consistently. A further breakdown of this response showed that seat hardness was the cause of the great majority of complaints (60 per cent of all complaints), next came complaints about seats not being the proper height (12 per cent), and finally, complaints about seats twisting and tilting around their supporting shafts (6 per cent). Of the 12 per cent who complained of the seat adjustment, many stated that the seat was not uncomfortable enough to necessitate an adjustment. There is further evidence then, that the present facility for seat adjustment is adequate.

Item seven is also of interest to this discussion. It asks what the subjects thought was unsafe about the machine. Few responses were given, but some of those which were concerned fears of the operators rather than actual problems encountered in the operation of the machine. Four males felt a danger that trouser legs could get caught in the pedal sprocket and one felt that the machine could tip over. On the other hand, feet did actually slip from the pedals often enough to prompt four complaints, and at least two people had difficulty mounting and dismounting. This was due to the fact that the pedals were often still in motion when rider changes were attempted. At no time during the evaluation, however, did these or similiar difficulties cause injuries to the operators.

Table VI

RESULTS OF POST-STUDY TELEPHONE INTERVIEWS

1. Question: "What were the hardest and the easiest work-rest conditions for you?"

Responses:	Schedule	Easiest			Hardest		
		Male	Female	Total	Male	Female	Total
(15 work, 7.5 rest)	1	4	7	11	12	8	20
(20 work, 10 rest)	2	4	4	8	2	5	7
(30 work, 15 rest)	3	10	11	21	6	11	17

2. Question: "Did you have any body soreness due to riding the bike?"

Responses:	Males Who Reported Yes	Females Who Reported Yes
	39 out of 49 (79.6%)	40 out of 52 (76.9%)

(Combined Total: 78.2%)

3. Question: "After which day on regular shift were you most fatigued?"

		Males	Females
Responses:	After First Day	14	20
	After Second Day	1	4
	After Last Day	4	4
	Not Tired	3	4
	No Response	17	10

4. Question: "Did you feel ill during or after riding the bike?"

Responses:	Males Who Reported Yes	Females Who Reported Yes
	3 out of 49 (6.1%)	9 out of 52 (17.3%)

(Combined Total: 11.9%)

Table VI CONTINUED

5. Question: "How much longer could you have operated on a regular shift?"

Responses: Number of Hours	Males	Females	Total
1	4	7	11
2	3	5	8
3	10	6	16
4	0	1	1
5	0	1	1
6+	7	2	9

6. Question: "What (if anything) didn't you like about the bike?"

Responses: Complaint	Males	Females	Total
Seats (too hard, not adjusted, loose)	41	36	77
Handle Bars (loose, not adjusted)	4	4	8
Pedals (feet slipping off)	7	0	7
Noise	1	3	4
Partner	1	2	3
Chain (looseness)	1	0	1

7. Question: "What (if anything) did you consider unsafe about the bike?"

Responses: Complaint	Males	Females	Total
Foot slipping off or getting caught on pedal	2	2	4
Fear of chain catching pants	4	0	4
Hard to get on	0	1	1
Hard to get off	0	1	1
Fear of tipping over	1	0	1

Operator Considerations

As described earlier, the operator evaluation was divided into three substudies. The Regular Shifts were primarily to determine the effects on team composition of varying the work-rest intervals. The Endurance Shifts were to determine if the various team compositions could operate selected work-rest schedules for nine hours. The No-Rest Shifts were to determine if various team compositions could operate for three hours without rest. The results are described below.

Regular Shifts

1. Individual Performance. The 51 Regular Shifts operated in this evaluation were ideally to have provided 17 completed cases. However, due to subject dropouts and removals, only 11 completed cases resulted. Dropouts were defined as those subjects who, after completing one or two shifts, did not return on the following day(s) to complete their participation. Removals were those persons who were allowed to stop operating during a shift, either because continuation was thourght harmful to their health or because they asked to be permitted to quit.

Since all Regular Shift subjects, with the exception of dropouts and removals, completed three shifts' participation, the data on individual performance can be viewed in terms of these exceptions. Table VII shows the Regular Shift dropouts and removals. In view of the information presented there, it is possible to reach several conclusions:

a. Seventy-six per cent of the subjects tested (ranging in age from 14 to 48) were able to operate all three days with an effective temperature range of 62 to 85.5 degrees.

b. All of the removals, and all but one of the dropouts occurred, respectively, during and following the first day of operation.

c. All removals occurred within two hours of the beginning of the first shift.

d. There were more dropouts than removals.

Table VII

REGULAR SHIFT SUBJECT DROPOUTS AND REMOVALS: STARTING SUBJECTS ONLY[1]

	Removals		Dropouts		Totals	
	Male	Female	Male	Female	Removals	Dropouts
First Day (by hour)						
1 hour or less	2	1	---	---	3	---
2 hours	1	1	---	---	2	---
3 hours	0	0	---	---	0	---
Subjects not returning after first day	---	---	2	4	---	6
Second day through the end of the third day	0	0	---	---	0	---
Subjects not returning after second day	---	---	1	0	---	1
					5	7

[1]Number of Subjects (N) = 51 (i.e., data included from all 17 potential cases)

Interpreting these facts from the standpoint of operating the PVK in an actual emergency, it can be said conservatively that three-quarters of any population of young people could be expected to perform the work-rest schedules tested without difficulty. Those who do have difficulty will usually experience it early, rather than after prolonged operation. Conversely, those who do not experience difficulty operating in the first hour or two should be able to operate to the limits tested. The limits tested, of course, were normally three-hour shifts. (However, it should

be noted that riders operating as members of the Open Shift teams performed as many as 13 consecutive days without difficulty.)

The significance of the fact that there were more dropouts than removals will be discussed later (see p. 62). It is desirable now to make some mention of operator performance as a factor of age.

The scarcity of subjects in the over-41 age range makes anything that can be said concerning them quite tentative. One fact, however, stands out to such an extent as to make plausible the argument that people in this age range can successfully perform on the PVK as required. This is: of the nine subjects who participated, all operated long enough to experience difficulties in operating if they were going to. However, none were removed. The one subject who dropped out stated, when being interviewed, that she could have done it but was "just lazy".

The initial attempt to have older persons operate the machine then leads to promising results. Certainly, many of the subjects tested were accustomed to heavy labor; but on the other hand, the mean Occupation-Exercise Scale value for the over-41's, as computed from the raw data, is below average for the subject population as a whole (mean value of 4.0). If these people could operate, then a rough and conservative guess would be that at least 50 per cent of the adult population could. The verification of this statement, of course, remains for further research.

2. Work-Rest Schedules. Table VIII shows lag time, overspeed time, and stop time in terms of the four possible team compositions and the three work-rest schedules, using only the completed cases. The values given are the averages of the middle hour of the completed shift because observer duties were lightest then and more careful measures could be obtained.

It is evident that the data provide no clear pictures as to which of the three work-rest schedules allowed the most efficient operation. No consistent trends are evident in lag time, overspeed time, or stop time. Item one of the telephone questionnaire (see Table VI, p. 44), which asked each subject to indicate the easiest and the hardest work-rest schedules,

Table VIII

TEAM COMPOSITION OF REGULAR SHIFTS BY PER CENT OF AVERAGE SHIFT LAG, AVERAGE SHIFT OVERSPEED, AND AVERAGE LENGTH OF INTER-SEGMENT STOP TIMES

Team Composition	Number of Completed Cases	Average Per Cent of Lag Per Segment				Average Per Cent Overspeed Per Segment				Average Length (In Seconds) of Inter-Segment Stop Time			
		Schedule:[1]				Schedule:[1]				Schedule:[1]			
		1	2	3	Average	1	2	3	Average	1	2	3	Average
3 Males (Composition A)	2	0	0	19	6.3	22	0	6	9.3	No Data	9	8	8.5
2 Males, 1 Female (Composition B)	2	67	50	39	52.0	2	0	0	0.6	10	5	No Data	7.5
1 Male, 2 Females (Composition C)	3	59	38	39	45.3	0	33	0	11.0	11	13	9	11.0
3 Females (Composition D)	4	95	58	99	84.0	31	0	0	10.3	6	37	14	19.0
Average	---	55	37	49	----	14	8	2	----	9	16	10	----

[1]Schedule 1 is 15 minutes work, 7.5 minutes rest. Schedule 2 is 20 minutes work, 10 minutes rest. Schedule 3 is 30 minutes work, 15 minutes rest.

proved only slightly more helpful. Here, the operators choose Schedule 3 (30 minutes work, 15 minutes rest) as the easiest, but there is a disagreement between the males and females as to which is the hardest. The fact, that Schedule 3 seems easiest, is confirmed by the group teams operating Open Shifts in which they were permitted to choose the schedule. Considering the three groups together, of the nine shifts (three per group) in which choice was allowed, seven shifts were operated as Schedule 3 and two shifts as Schedule 2.

On the other hand, Table IX shows that, although dropouts occurred most frequently following Schedule 1, removals occurred most frequently on Schedule 3. Postulating dropouts to be simply a function of flagging motivation on the part of the subject, and removals to be more a function of real or imagined inability to operate, then, in an emergency situation where high level of motivation would supposedly be present, factors leading to removals would be worthy of more serious consideration. Table IX then, would be presenting a telling argument against Schedule 3 as an optimal work-rest interval in actual operation of the PVK.

Table IX

DROPOUTS AND REMOVALS IN TERMS OF REGULAR SHIFT WORK-REST SCHEDULES[1]

Schedule	Dropouts			Removals		
	Male	Female	Total	Male	Female	Total
1 (15 minutes work-7.5 minutes rest)	1	3	4	1	0	1
2 (20 minutes work-10 minutes rest)	1	1	2	0	0	0
3 (30 minutes work-15 minutes rest)	1	0	1	2	2	4

[1]Number of times a schedule presented first in a potential case: Schedule 1, seven times; Schedule 2, four times; Schedule 3, six times.

Seemingly, in the face of this conflicting data, the only thing that can be said with certainty is that, within the range tested, the work-rest schedule used was not critical to the successful operation of the PVK with regular, three-hour shifts.

It is quite possible that the problem of work-rest schedules may never arise in an actual shelter situation (assuming that a large number of shelterees are available who are capable of operating the machine), or that, if a problem did arise, the shelter manager could very likely make an on-the-spot, "common-sense" judgment without danger of reducing the probability of survival. However, nothing would be gained by remaining blind to possible dangers resulting from seriously overworking the shelterees. It would be desirable then, to examine further the problem of work-rest schedules.

3. Team Composition. Two important facts were noted in the data resulting from the Regular Shifts: (1) All-male shifts lag much less than all-female shifts, with the mixed shifts falling somewhere in between; and (2) the stop times show the same trend as lag times; that is, higher values for all-female shifts. (See Table VIII, p. 49.) .

It is possible to give two interpretations to this information: (1) The female riders may simply be exercising their prerogative as the "weaker sex"; that is, they may view the operation of the machine as "man's work" and may enter the experimental situation with a predisposition toward operating at below the expected level; and (2) they may, on the other hand, be physically incapable of operating at that level. In the first case, no real difficulty could be extrapolated to the actual shelter situation since, under emergency conditions, conceivably the women would be motivated to forget the sex distinction. In the case of physical inability, however, a more serious problem could exist in which female operators would not be able to successfully ventilate their shelter.

A breakdown of completed-case, subject-volunteered fatigue reports for both Regular and Endurance Shifts is found in Table VI, p. 44. The data show that only four reports of fatigue were made during Regular Shifts, but all of these were made by females. It would seem then that there is

evidence in favor of the second interpretation. Further support of this view comes from the telephone questionnaire (see Table VI, p. 44). Item four asked whether or not the subject felt ill during or after operating the PVK. Seventeen per cent of the women, as opposed to only six per cent of the men, indicated that they experienced illness.

Here, too, equivocal evidence demands that caution be exercised in interpretation. Table X shows Regular-Shift dropouts and removals in terms of team composition. It is clear that the table does not show females as being more often removed or as dropping out more often.

Table X

Dropouts and Removals in Terms of Regular Shift Composition[1]

Composition	Dropouts			Removals		
	Male	Female	Total	Male	Female	Total
A (3 Males)	2[2]	0	2	3[3]	0	3
B (2 Males, 1 Female)	0	0	0	0	0	0
C (1 Male, 2 Females)	1	2	3	0	0	0
D (3 Females)	0	2	2	0	2	2

[1]Number of times a composition existed on the first day of a potential case: Composition A, five times; Composition B, three times; Composition C, four times; Composition D, five times.

[2]Number of subjects droping out after completing composition.

[3]Number of subjects removed during the operation of composition.

If, as postulated in the earlier report (Ref. 4, p. 38), females operating in mixed shifts tend to let the male(s) do most of the work, male dropouts and removals in the mixed Compositions B and C should show an increase over A and D Compositions. This is obviously not the case except in reference to Composition C dropouts, where the interview with the male subject resulted in the volunteered comment that he had dropped out because it was hard operating with girls.

Endurance Shifts

1. Individual Performance. The most important question investigated by the Endurance Shift testing was that of the capability of a human operator to maintain operation of the PVK for nine hours. Ignoring team composition and work-rest schedule for the moment, it is apparent from the data in Table XI that 7 out of 18 subjects assigned to this shift condition were able to complete 9 hours of operation. Moreover, only 2 of the 18 assigned subjects were unable to operate more than 3 hours. It should be remembered, however, that no subjects over 26 years old were used in any of the Endurance Shifts.

Table XI

Number of Hours Endurance-Shift Subjects Operated: Starting Subjects Only

Hours	Male	Female	Total	Cumulative Frequency
3 (or less)	1	1	2	18
4	0	0	0	16
5	0	2	2	16
6	2	1	3	14
7	0	1	1	11
8	3	0	3	10
9	4	3	7	7
Mean Number of Hours	7.5	6.6	7.1	---
Number of Participants	10	8	18	---

On the basis of the data from Table XI, it is possible to conclude:

a. Approximately 39 per cent of the assigned subjects (ranging in age from 14 to 26) were capable of operating the PVK for 9 hours or more with an effective temperature ranging between 65.5 degrees and 79 degrees.

b. Approximately 89 per cent of the assigned subjects were able to operate longer than a 3-hours shift.

c. Approximately 50 per cent of those tested were capable of operating 7 hours or more.

This last finding is supported by item five in the telephone questionnaire (see Table VI, p. 44). The item asks how much longer subjects thought they could operate a Regular-Shift condition. Fifty-eight per cent felt they could operate three hours or more longer.

Since some teams required a replacement for a starting rider who was removed, data were also analyzed in terms of the longest operating riders on a shift (see Table XII). By taking the average hours worked by the three longest operating subjects (as opposed to those subjects starting the shift, as in Table XI), Compositions A, B, and D show higher values than would be expected from Table XI. In all likelihood, this means that the average values in Table XI are on the conservative side, and that the mean of subjects could be expected to exceed those values.

In brief then, the optimal shift length will depend upon the shelter situation. If it is desired to conserve the strength of the operators, shift lengths of less than three hours are called for. However, if necessary, persons can operate at least nine hours, assuming that they are young and in good health. Most people should be able to pedal for six hours or more, provided that a work-rest schedule of the types tested is used.

2. Work-Rest Schedules. As noted earlier, Endurance Shifts were operated using both work-rest Schedules 1 and 3; only team Compositions A and D operated both schedules.

Table XII

ENDURANCE SHIFT: A BREAKDOWN OF RELEVANT VARIABLES

Composition	Number of Shifts	Average[1] Hours Worked	Average Per Cent Shift Lag	Average Per Cent Shift Overspeed	Average Inter-Segment Stop Time (Seconds)
A (All Males)	2[2]	8.0	5.5	2.5	9
B (2 Males, 1 Female)	1	8.0	48.0	1.0	13
C (1 Male, 2 Females)	1	4.6	29.0	1.0	8
D (All Females)	2[2]	7.7	46.0	1.0	15

[1]Using the three longest operating subjects per shift. (Includes relief riders; i.e., subjects replacing those removed from the bike.)

[2]Compositions A and D were run using both work-rest Schedules 1 and 3; no consistent differences were noted between the two schedules.

On the basis of informal evaluation of the lag, overspeed, and stop-time measures, it can be stated that the Endurance-Shift data show nothing contradictory to the earlier impression that: (1) No one schedule was unequivocally best, and (2) none of the schedules tested critically reduced the operator efficiency.

The data from the subject-volunteered fatigue reports (Table XIII), including information from both Regular and Endurance Shifts, do show a pronounced trend in favor of Schedule 2 (20 minutes work, 10 minutes rest); and it shows Schedule 3 (30 minutes work, 15 minutes rest) as being complained about most in both substudies. While it is possible to argue that Schedule 2 was least complained about merely because it represented a

middle-of-the-road condition; i.e., containing neither the longest working period nor the shortest resting period of those schedules tested; the fact that Schedule 3 received by far the highest number of complaints cannot be easily explained. Certainly, when subjects were asked to indicate which of the schedules were easiest and hardest, Schedule 2 was mentioned least in both cases. On the other hand, in this same item (item one of the telephone questionnaire, Table VI, p. 44), both sexes indicated that Schedule 3 was the easiest to perform.

To make a final comment as to which work-rest schedule tested is preferable (bearing in mind that none were either critically good or bad), it is necessary to stand in favor of Schedule 3. The reason for this is simply that removals represent such a small percentage of the total number of operators (7 per cent of the starting operators of both Regular and Endurance Shifts) and assuming that 65 per cent of these were removed only because the operators wished to quit, the number of valid cases of fatigue do not balance the positive effect of having the operators perform a schedule which they consider easiest.

3. Team Composition. In all, six teams participated in the Endurance Shifts; none were eliminated in the evaluation of the data. No shift was able to complete the nine-hour run without the removal of at least one of its riders. Two runs, however, were completed with two of the starting riders still operating; three runs were completed with one of the starting riders.

The values of lag time, overspeed time, and inter-segment stop time for Compositions A and D tend to support the Regular Shift claim that at the present required output, female teams cannot, in general, operate as well as all-male teams. The Endurance-Shift fatigue reports given in Table XIII give further support to this claim by indicating that two-thirds of those who complained were female.

In all fairness to the female operators, it must be admitted that mixed compositions do not perform as would be expected by the hypothesis that the more female operators on a shift, the lower the over-all efficiency. Comparing the lag times for Regular Shifts (Table VIII, p. 49) and Endurance

Table XIII

SUBJECT-VOLUNTEERED FATIGUE REPORTS FOR REGULAR AND ENDURANCE SHIFTS[1]

Type of Shift	Comp. A	Comp. B	Comp. C	Comp. D	Sched. 1	Sched. 2	Sched. 3	Sex		Total
	3 Males	2 Males, 1 Female	1 Male, 2 Females	3 Females	15 Work, 7.5 Rest	20 Work, 10 Rest	30 Work, 15 Rest	Male	Fem.	
Regular Shifts	0	0	2	2	1	1	2	0	4	4
Endurance Shifts	3	1	3	5	4	---	8	4	8	12

[1]Only completed cases used; Regular Shifts = 11, Endurance Shifts = 6.

shifts does not show the rise expected from A through D. Indeed, shifts with two female riders lag less than shifts with one female rider. Comparisons of overspeed and stop times also fail to show the respective gradients, and for both measure there is disagreement between the gradients found in the Regular and Endurance Conditions.

No-Rest Shifts

1. Individual Performance. Table XIV presents the breakdown of hours operated by No-Rest subjects. The question, "Can it be done?" is again answered in the affirmative with 41 per cent of the subjects able to complete the 3-hour shift.

Table XIV

TIME OPERATED BY NO-REST SHIFT SUBJECTS: STARTING SUBJECTS ONLY

Hours	Male	Female	Total	Cumulative Frequency
0.5 (or less)	0	2	2	22
1.0	1	3	4	20
1.5	1	1	2	16
2.0	1	1	2	14
2.5	2	1	3	12
3.0	8	1	9	9
Mean Number of Hours	2.6	1.4	2.1	----
Number of Participants	13	9	22	----

On the basis of the information found in Table XIV, it is possible to make these statements:

a. A significantly higher percentage of males (61 per cent) than females (11 per cent) were able to complete the No-Rest Shift with effective temperature ranging between 71.5 degrees and 81.5 degrees.

b. More than half the subjects were able to operate 2 hours or more.

c. Approximately 99 per cent of the subjects could operate 1 hour or more.

As with the Endurance date, calculating the average hours worked, in terms of the two longest operating subjects from each shift (see Table XV), provides higher values than would be expected from Table XII. Therefore, in all probability, the Table XIV values are also conservative.

Table XV

NO-REST SHIFT: A BREAKDOWN OF RELEVANT VARIABLES

Composition	Number of Shifts	Average Hours Worked[1]	Average Per Cent Shift Lag	Average Per Cent Shift Overspeed
E (2 Males)	2/3[2]	2.7/2.9	0/26	7/4
F (Mixed)	2/1	1.9/2.5	11/0	1/15
G (2 Females)	1/2	1.9/2.5	5/25	1/1

[1]Using the two longest operating subjects from each shift.

[2]New/experienced teams.

2. <u>Team Composition</u>. Of the 12 teams initially scheduled to operate No-Rest Shifts, one was removed from the sample when it was discovered that it had included both new and experienced operators. Of the 11 remaining teams, 3 male shifts were able to complete without the use of the relief rider; only 1 shift occurred in which the relieved rider was too fatigued to act as a stand-by herself.

Information relevant to differences in efficiency between new and experienced teams can be found in Table XV. It is evident from the average hours worked that, for all compositions, experienced team members were able to operate longer on the average than were new, inexperienced team members. Lag time for the all-male and all-female teams, however, is much higher.

This leads one to postulate that experienced teams, because of previous practice and greater familiarity with the experimental situation, the apparatus, and their own ability to successfully operate the apparatus, were better able to operate. The high lag can be explained in terms of the experienced teams being less motivated to maintain speed, as they knew no punishment would result from their failure to do so.

It would seem then, that in an emergency situation, more efficient operation can be expected as the shelterees gain experience with the PVK. It would seem also, that due to the high and relatively immediate reward resulting from the operation of the PVK to maintain a livable atmosphere, the problem of lagging would either not occur or would be quickly resolved, if it did occur, through the knowledge that worsening conditions resulted.

Returning to the subject of the female teams' inability to perform to the standard as well as males, it could be said that the average hours worked information in Table XV gives additional support to this point. However, overspeed data from the table and the data on No-Rest, subject-volunteered fatigue reports from Table XVI are in contradiction to such an interpretation. In the No-Rest Condition, females operated overspeed for the greatest average per cent of the time, and complained less of fatigue (combining data from both the new and experienced teams). In addition, males appear to have nearly as great a lag time. Final conclu-

sions concerning the female's ability to operate at the required standards of speed and endurance must remain for further study. In general, it is safe to say that all-female teams can be expected, for whatever reason, to perform less efficiently in terms of speed and endurance than all-male teams, and, as recommended in the earlier report, female teams should be used only when men are not available. If used, women should be more closely supervised and encouraged to maintain the required speed, and provision should be made for a more frequent change of operators.

Table XVI

NO-REST SHIFTS: SUBJECT-VOLUNTEERED FATIGUE REPORTS BY TEAM COMPOSITION AND SEX

Composition	Number of Subjects	Number of Subjects Complaining	Per Cent of Subjects Complaining
E (2 Males)	12	7	58
F (Mixed)	10	2	20
G (2 Females)	9	3	33
Sex: Male	17	8	47
Female	14	5	36

Supplementary Data Relevant to Operator Considerations

During the processing of the data generated in the evaluation, information presented itself which, while interesting and important, did not lend itself to treatment as part of any of the major substudies. These data concern: (1) subjects removed from the PVK, and (2) subject cracker-and-water consumption.

1. Subjects Removed from the Apparatus. In general, subjects removed from the bike fell into two classes: (1) those who asked to be removed because they did not want to continue, and (2) those whom the observer removed out of consideration for the subjects' safety. Two categories of riders, however, were not considered removals:

a. Those subjects who simply did not attend subsequent shifts, i.e., dropouts.

b. Those No-Rest subjects who asked to be removed but stayed to finish the shift whether or not they rode again on the shift.

On this basis, 17 subjects were removed from the machine -- 65 per cent of which asked to be removed.

Careful review of the information gathered concerning these removed subjects provides no systematic evidence as to why they should have been incapable of operating the required length of time. Subjects were arranged on an underweight-overweight continuum as shown in Table XVII. It is evident from this table that few of the subjects could be considered extremely deviant from the standpoint of weight. Indeed, none of the parameters examined, including height, weight, age, and position on the Occupation-Exercise Scale, show any significant trend.

It is probable that most if not all of those subjects removed by the observers were in no real danger of overwork. Indeed, most claimed that they were feeling no fatigue. Still, observers were instructed to remove anyone whose pulse and/or blood pressure exceeded certain levels (see pp. 39-40)for removal criteria) regardless of his appearance, in order to minimize the danger of subject overwork. The problem of those asking to be removed is somewhat different; often riders volunteered to discontinue operating the machine even though their pulse and blood pressure measures were well within specifications.

A further consideration of this problem leads to the conclusion that the problem lies (1) in the motivation of the rider and (2) in the subject's fear that the machine might cause him to overwork. So far as a real emergency

situation is concerned, the problem of motivation largely will take care of itself, due either to the operator's own fear for survival or the social pressures exerted on the operator by the other shelterees. The operator's fear of overwork can be most easily overcome by allowing the fearful operator to perform for short periods initially, until he gets a clearer idea of what to expect from himself and the machine.

Table XVII

Range of Underweight and Overweight in Subjects Removed from Apparatus

Underweight/Overweight	Male	Female
30-21 pounds underweight	1	1
20-11 pounds underweight	1	0
10-0 pounds underweight	1	3
1-10 pounds overweight	1	5
11-20 pounds overweight	1	1
21-30 pounds overweight	0	C
31-40 pounds overweight	0	1
41-50 pounds overweight	1	0
Total	6	11

NOTES:

1. Ref 6 -- Criteria for subjects nineteen years of age and over.
2. Ref 7 -- Criteria for subjects 18 years of age or less.

2. Food Consumption. A loose attempt was made during the Endurance and No-Rest Shifts to measure the subjects' consumption of OCD crackers and water. The results are shown in Table XVIII. Two trends were noted:

a. Males consumed more water and crackers per shift than did females.

b. Experienced groups tended to consume less water and crackers per shift than did new operators.

Table XVIII

ENDURANCE AND NO-REST SHIFTS: FOOD AND WATER CONSUMPTION

Composition	Endurance Shifts		No-Rest Shifts	
	Water[1] Consumption (Cups)	Food[1] Consumption (OCD Crackers)	Water[1] Consumption (Cups)	Food[1] Consumption (OCD Crackers)
A (All Male)	5	4	4/2[2]	1/0
B (2 Male, 1 Female)	3	5[3]	4/3	0/0
C (1 Male, 2 Female)	1	1	---	---
D (All Female)	3	2	---	---
F (1 Male, 1 Female)	---	---	3/2	1/0

[1]Per subject per shift.

[2]New/experienced conditions.

[3]This figure is the result of 1 subject consuming 17 crackers during the 9-hour shift; other team members had no more than 1 cracker each. The figure, therefore, represents a quite deviant situation.

In view of the seeming fact that males worked harder on the apparatus than did females, it is not difficult to discover significance in the first finding. The second finding, however, is quite unexpected. If it is true that teams who have operated before eat and drink less than teams who have never ridden, it may well be that, in an actual shelter which is ventilated manually, the increase in food and water consumption following the start of the ventilation operation may be partly a temporary condition which can be planned for, and the subsequent reduction of consumption maximized. Before anything further can be said on this topic, however, the whole area of operator food consumption must be more carefully investigated.

Summary of Results

1. Individual Performance. Collecting and unifying the individual operator performance results of each substudy lead to the following set of conclusions as to what can reasonably be expected in terms of a person's ability to operate the PVK. Based on the population tested (males and females aged 14 to 48) with effective temperature ranging from 62 degrees to 85.5 degrees.

a. Roughly 75 per cent can operate the PVK for 3 hours on a work-rest schedule such as those tested.

b. Any inability to operate will tend to manifest itself early in the term of PVK operation. Inability due to fear of the possible consequences of operating can be dealt with by allowing the rider to perform for short periods of time initially.

c. Fifty per cent can operate for seven hours or more on a work-rest schedule. When necessary, most of these could be expected to operate nine hours without ill effect.

d. Ninety per cent should be able to operate for one hour or more without rest. On the average, males were able to operate without rest for two and one-half hours; females, for one and three-quarter hours.

e. In a no-rest operation (and, it is assumed, in the operation of a work-rest schedule), experience team members can be expected to operate longer, on the average, than inexperienced team members.

2. Work-Rest Schedule. Concerning the work-rest schedules tested (15 minutes work, 7.5 minutes rest; 20 minutes work, 10 minutes rest; and 30 minutes work, 15 minutes rest), it can be said that:

a. None were critical to the successful operation of the PVK.

b. The 30 minutes work, 15 minutes rest schedule must be considered the most acceptable since the fact that it was thought easiest to perform outweighed other negative factors.

3. Team Composition. Three findings were basic to the present treatment of team composition. It can be said that:

a. Teams composed exclusively of males perform more efficiently than those teams composed exclusively of females.

b. Although not conclusive, some evidence exists to suggest that, of the mixed shifts, the two female, one male is less efficient.

c. The scattering and inconsistency of data indicate the presence of other factors affecting the efficiency of mixed teams. Further investigation would be necessary to precisely determine the nature and relative efficiency of mixed-composition teams.

APPENDIX A

SHELTER RESEARCH LABORATORY, AMERICAN INSTITUTES FOR RESEARCH

410 Amberson Avenue, Pittsburgh 32, Pennsylvania   681 - 3000

APPLICATION FORM
(Please Print or Type)

1. Full Name:________________   2. U.S. Citizen: Yes___ No___

3. Home Address:________________   4. Home Phone:________

5. Occupation:________________   6. Business Phone:________

7. Business or School Address:________________

8. Sex:________   9. Age:________

10. Religious Preference:________________   11. Marital Status:________

Ages of Children: 12. Girl(s):________   13. Boy(s):________

14. Nature of Previous Employment:________________

15. Military Experience, Rank:________________

16. Civil Defense Experience:________________

17. Education: Grade Completed:________

College Experience:________________

18. Height:________

19. Weight:________

20. Do you have heart trouble?________   Diabetes?________

21. Do you have or have you ever had any respiratory disease (TB, asthma, etc.)?______

22. Have you been hospitalized or had any serious illness in the last 6 months?______

23. Are you presently under the care of a doctor, psychiatrist, or counselor? If so, for what?________________

24. Give name, address, and phone number of your personal physican:________________

____

25. Have you received professional help for an emotional or nervous disorder within the past three years?________

26. Why are you interested in participating in this study?________________

27. When can you participate in the study?________________

28. Would any friends, associates, or members of your family be interested in participating in these studies? (Use other side if necessary.)

NAME	AGE	ADDRESS	PHONE	RELATIONSHIP

MEDICAL RECOMMENDATION

Name of Participant____

Address____

To the Physician:

The above named person has applied to the American Institutes for Research to become a subject in the experiment described below. On the basis of your knowledge of this person's physical condition and health history, please recommend this person by checking one of the alternatives listed at the bottom of this page.

A subject in this experiment would be expected to pedal a stationary bicycle apparatus under a load similiar to that required to pedal a bicycle on a smooth, level highway. Subjects will pedal approximately 20 minutes and rest 10 for periods of from 1 to 3 hours depending on experimental design and your recommendation. Subjects will probably not work more than a total of three hours in any one day, but may work several days in succession.

If further information is desired, call the American Institutes for Research, Shelter Laboratory, 681-3000.

I recommend this person: ____for FULL participation in the experiment as described above.

____for QUALIFIED participation (explain on reverse side).

____be EXCLUDED from participation.

Signature of Physician______________________________ Date__________

QUESTIONNAIRE TO BICYCLE PEDALERS
August 1965

Name______________________________ No.__________ Age__________

Occupation____

____

Pastimes and normal amount of exercise________________________

____

Number of Shifts Worked__________

Regular Shift Condition: 1_____ 2_____ 3_____

Endurance Shift______________________________

No-Rest Shift________________________________

Which of the Regular Shift Work-Rest Conditions was hardest? Easiest?__________

____

After which days were you most fatigued?______________________

____

Any body soreness? How severe? How soon did it disappear?_____________

____

____

Did you feel ill at any time during or after riding? When? After which condition or type of shift? Reasons?__________________________________

____

____

Did you go full shift?_______ If so, how much longer could you have continued? If not, why did you stop?___________________________________

____

____

What did you like least about the apparatus itself? What was the most uncomfortable? Anything unsafe?____________________________________

____

____

ADDITIONAL COMMENTS:

APPENDIX B

BIKE PEDALING OBSERVER NOTES

Until Further Advised, Record the Following Data:

1. Complaints. Who is complaining, what position, what is complaint. A complaint may be about the machine, the subjects' own fatigue or body soreness, or anything that would be important were this machine being used in the real disaster or attack situation.

2. Pulse. Pulse should be taken by the subject himself at the beginning and end of his rest periods. To assure that the subjects take accurate readings, instruct them during their pre-shift time. Be sure to get a base-line pulse measure.

3. Blood Pressure. Blood pressure should be taken at the beginning of the subject's rest period. Be sure to get a base-line measure on each operator here too.

4. Lag Time. Estimate the amount of time each segment falls below the set speed. Indicate 0-10-20-30-40-50-60-70-80-90 or 100% lag.

5. Overspeed Time. Estimate the amount of time each segment operates above set speed as above.

6. Stop Time. Measure with the stop watch the amount of time the machine is stopped. The subjects should be unaware that this measure is being taken.

7. Adjustments. Just in case you haven't been doing it, record any adjustments made to the machine either by the subjects themselves (straightening the seat, adjusting the handle bars, etc.) or the staff.

8. Temperature. Take wet- and dry-bulb temperature readings once an hour.

9. Food and Water Consumption. Only shelter crackers and water should be allowed for the subjects. Crackers should be offered to the subjects after they have been on shift 2-1/2 hours, and the actual amount consumed should be recorded. Note if they ask for food before then. Water can be given on demand; record consumption in cupsful.

10. Shelter Information Questionnaire. This questionnaire should be given to the subjects as they finish their shift. No instructions should be required.

11. No-Rest Shifts. Beginning at 6:00 A.M. Sunday, August 15, twelve No-Rest Shifts will be run (please note, however, that one shift, the 6:00 to 9:00 P.M. Sunday, is regular). As the title indicates, riders will operate with no rest until they feel they can no longer operate or until the observer feels that they would be endangering themselves to operate further. Three subject compositions will be tried: all male, all female, and mixed. Two conditions: new riders or experienced riders. Three riders have to be scheduled for each shift as usual (the third subject will stand by). It is imperative that the proper subjects begin the shift. For example, a shift scheduled as all male (code A) may contain one female rider; the males would ride first and the female would be allowed to rest as a standby. In the same way, an all-female shift (code D) may contain one male rider. Of course, a mixed shift (code E) must begin with one male and one female rider on the bike.

In the event that a person is relieved from the bike, the standby rides that position (also with no rest). The relieved rider rests and stands by to relieve. If at any time a rider is forced to quit entirely due to high pulse, high blood pressure, or extreme fatigue, a replacement should be telephoned in the usual manner. The decision to use the regular rider or get a fresh rider will be left to the observer. Don't take chances with the health of our subjects.

The largest problem you will face will be taking pulse and blood pressure measures with the subjects riding. Better practice this when you get the chance. Be aware also, of pallor, heavy perspiration and breathing, and severe body pains as evidences of extreme fatigue.

Subjects must maintain red line. Remind them as often as is necessary.

NOTE: The timer can be made to sound at 7.5, 10, or 15 minutes simply by changing the gear assembly beneath the timing cam. It's a simple job, and in view of the fact that the above three values will be used for segment length, you will probably be required to change gears at one time or another. So, if you don't know how, ask.

SUPPLEMENT II

PACKAGE VENTILATION KIT:

MOTOR TEST

INTRODUCTION AND DESCRIPTION OF MOTOR TEST

The Civil Defense fallout shelter ventilating fan developed under Contract OCD-PS-64-22 and being procured under Specification MIL-V-40645, "Package Ventilation Kit, 20-Inch Fan, Modular Drive (Civil Defense)" includes an electric motor (see Figure 16). This motor is a permanent-split capacitor (PSC) type rated at 1/3 horsepower, 1100 rpm, 115 volts, 60 cps, 1-phase, and has class A insulation. The General American Research Division conducted a temperature rise test per NEMA Code (Ref. 8) on an Emerson Electric Mfg. Co. motor (Model K55HXCTD-1916) to verify that this motor meets the requirements of the above specification.

The test motor was mounted on a Package Ventilation Kit consisting of one Fan Assembly and one Drive Module as illustrated in Figure 17. Attached to the shroud of the fan assembly was a ten foot long section of flexible four-mil thick polyethylene duct. The opposite end of this duct was attached to a twelve-foot length of twenty-inch diameter rigid duct. A rope was placed around the periphery of the plastic duct at the intersection of the plastic duct and the rigid duct to provide a flow restriction. Cinching of the rope provided a variable orifice which could be controlled accurately to maintain the required static pressure and air flow equivalent to a motor output of 1/3 horsepower. Input power to the motor was connected through a Weston Model 329 polyphase wattmeter which is compensated for internal power losses and accurate to $\pm$ 2 watts. According to the test data furnished with the motor (see Figure 18) a 1/3 horsepower output is equivalent to approximately 410 watts. This input wattage, plus or minus ten watts, was maintained throughout the test period.

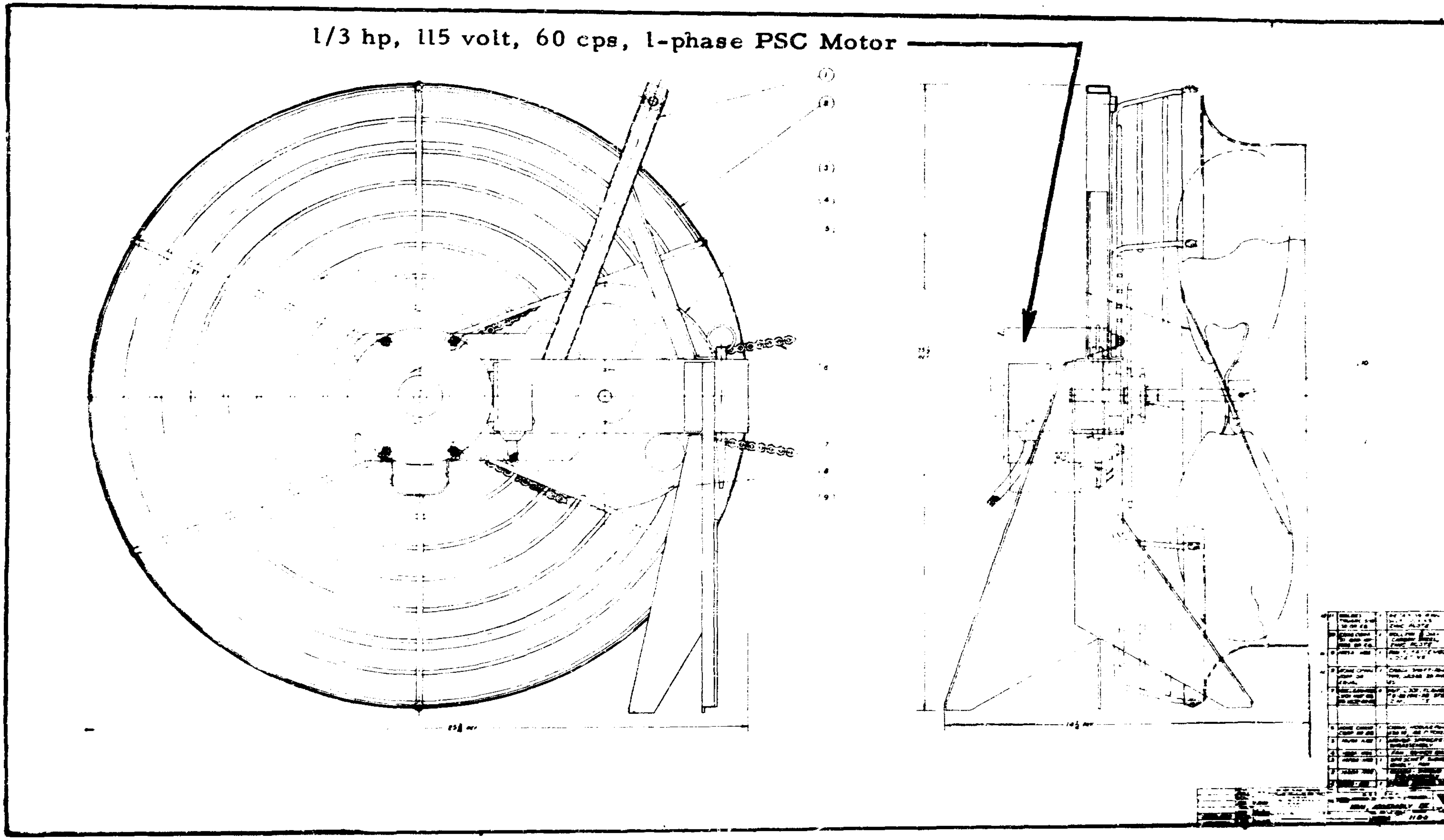

Figure 16 FAN ASSEMBLY

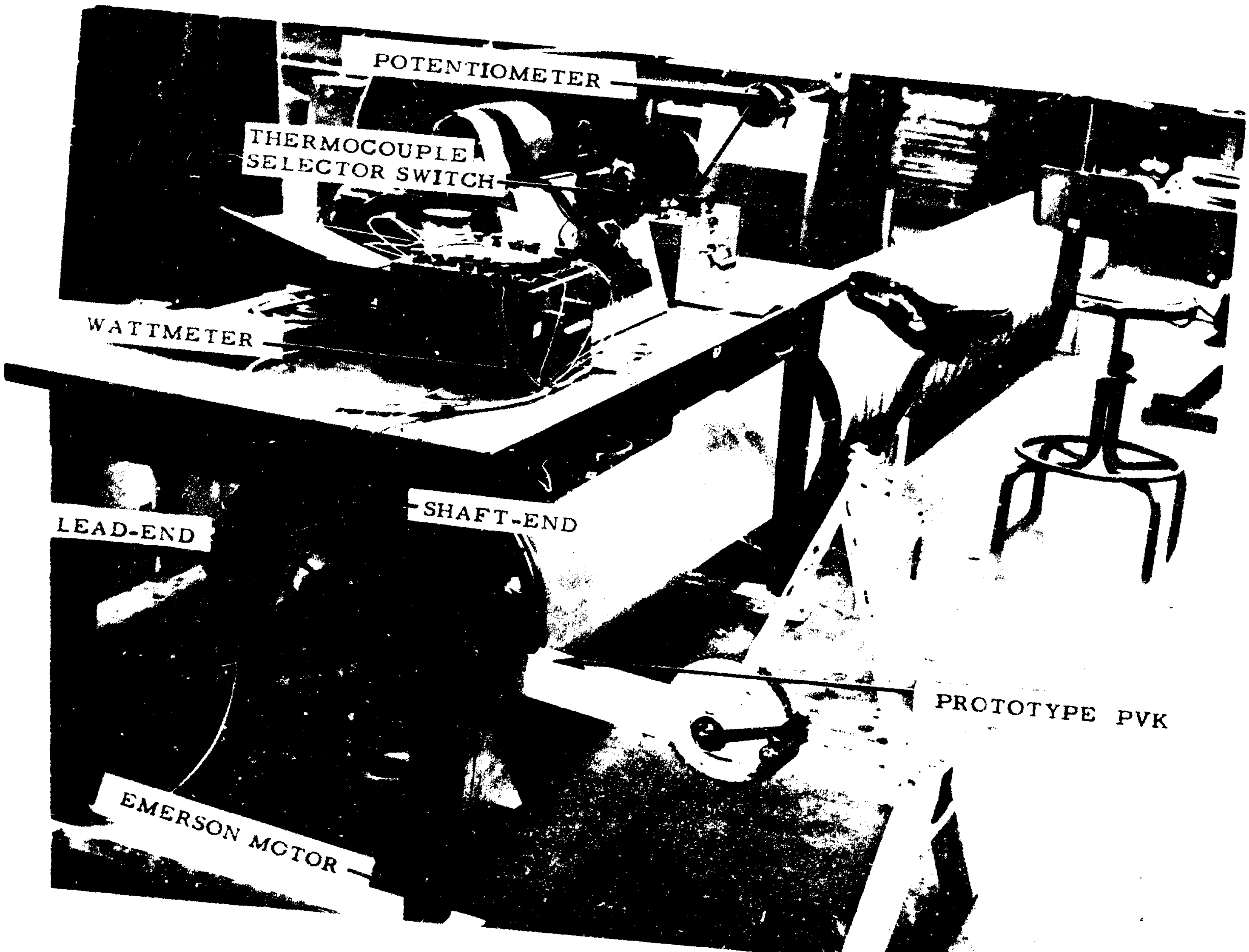

Figure 17 MOTOR TEST LABORATORY SET-UP

Two iron-constantan thermocouples were supplied with the motor -- one thermocouple imbedded in the auxiliary winding near the shaft end, and the other thermocouple imbedded in the main winding at the lead end. This thermocouple arrangement supplied winding temperatures of both coils, as well as an indication of the temperature difference from the shaft-end to the lead-end of the motor. An additional iron-constantan thermocouple was located approximately eight inches ahead of the lead-end of the motor to determine the temperature of the ambient air cooling the motor. All thermocouples were referenced to an iron-constantan thermocouple immersed in an ice-water bath, and all thermocouple emfs were measured with a Rubicon Model 2733 potentiometer.

Input power and thermocouple emfs were measured every fifteen minutes from the start of the test until the motor windings reached an equilibrium temperature. Thereafter readings were taken hourly for eight hour periods during the following three days. As the test period proceeded, it became apparent that winding temperatures were essentially constant and thus four temperature measurements per day were sufficient. During the final three hours of the test, the motor was stopped and started at ten minute intervals and temperature measurements were taken every half-hour.

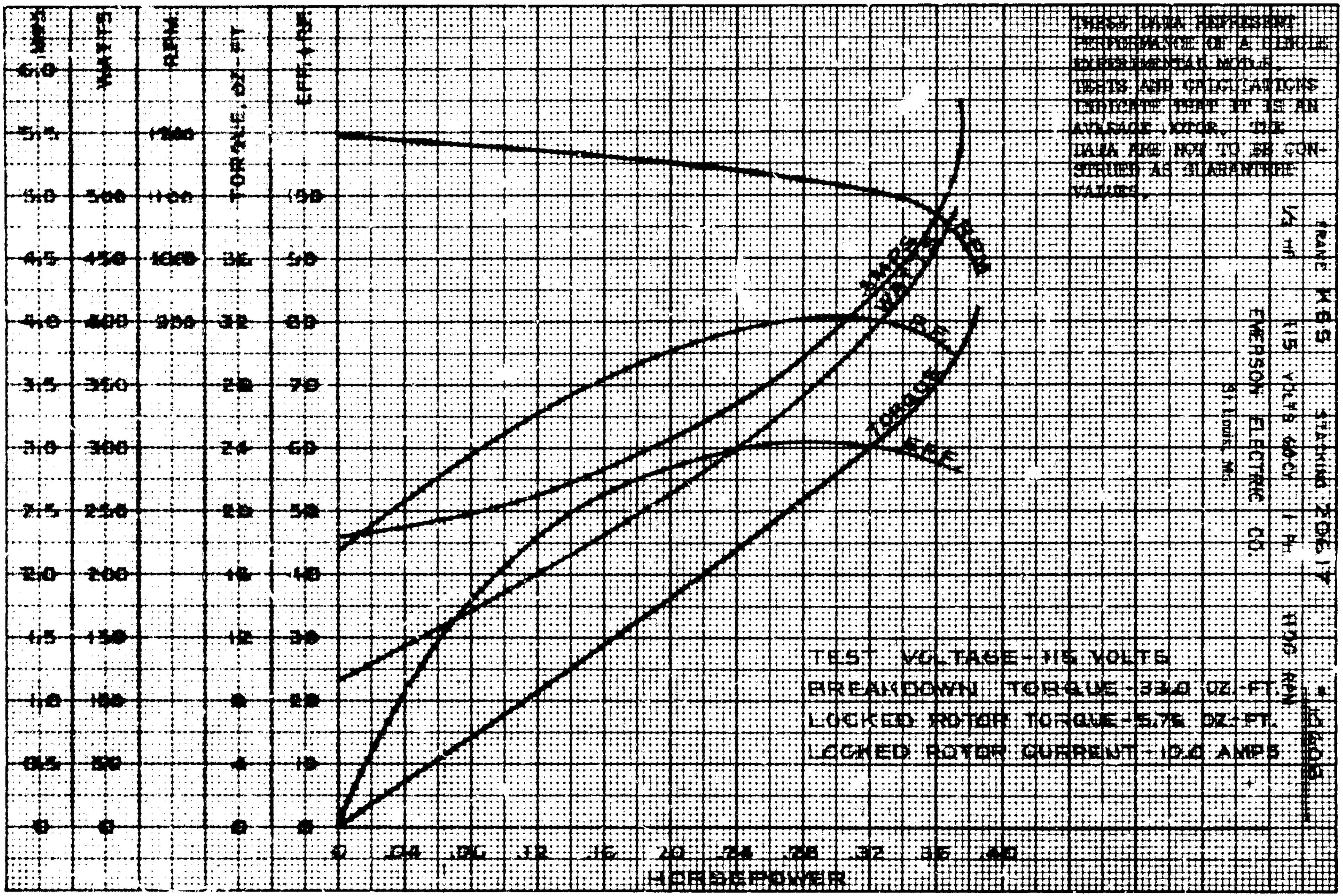

Figure 13 MOTOR PERFORMANCE DATA -- EMERSON ELECTRIC MFG. CO.

RESULTS OF MOTOR TEST

Figure 19 illustrates the temperature rise of the auxiliary and main windings for the Model No. K55HXCTD-1916 Emerson motor. The difference in temperatures between the auxiliary and main windings is attributed to the location of the thermocouples imbedded in each winding and is indicative of the temperature profile from the lead-end of the motor to the shaft-end. The maximum winding temperature rise attained throughout the fourteen day period was 26.5°C, and the ambient air temperature during the test ranged from 17.4 to 25.4°C. The test site elevation is approximately 600 feet. For motors that may be used at elevations up to 5500 feet, the maximum permitted temperature rise during tests at elevations of 3300 feet or less is 56.0°C (Ref. 9). Therefore, this motor meets the winding temperature limitations of the National Electrical Manufacturers Association for operation at ambient temperatures as high as 40°C (105°F). This motor also meets the Underwriters Laboratories (UL) standards for approval. UL requirements are that the maximum winding temperature shall not exceed 100°C when tested at an ambient temperature of 25°C. No increase in temperature rise was noted during the three hour start-stop period of the test.

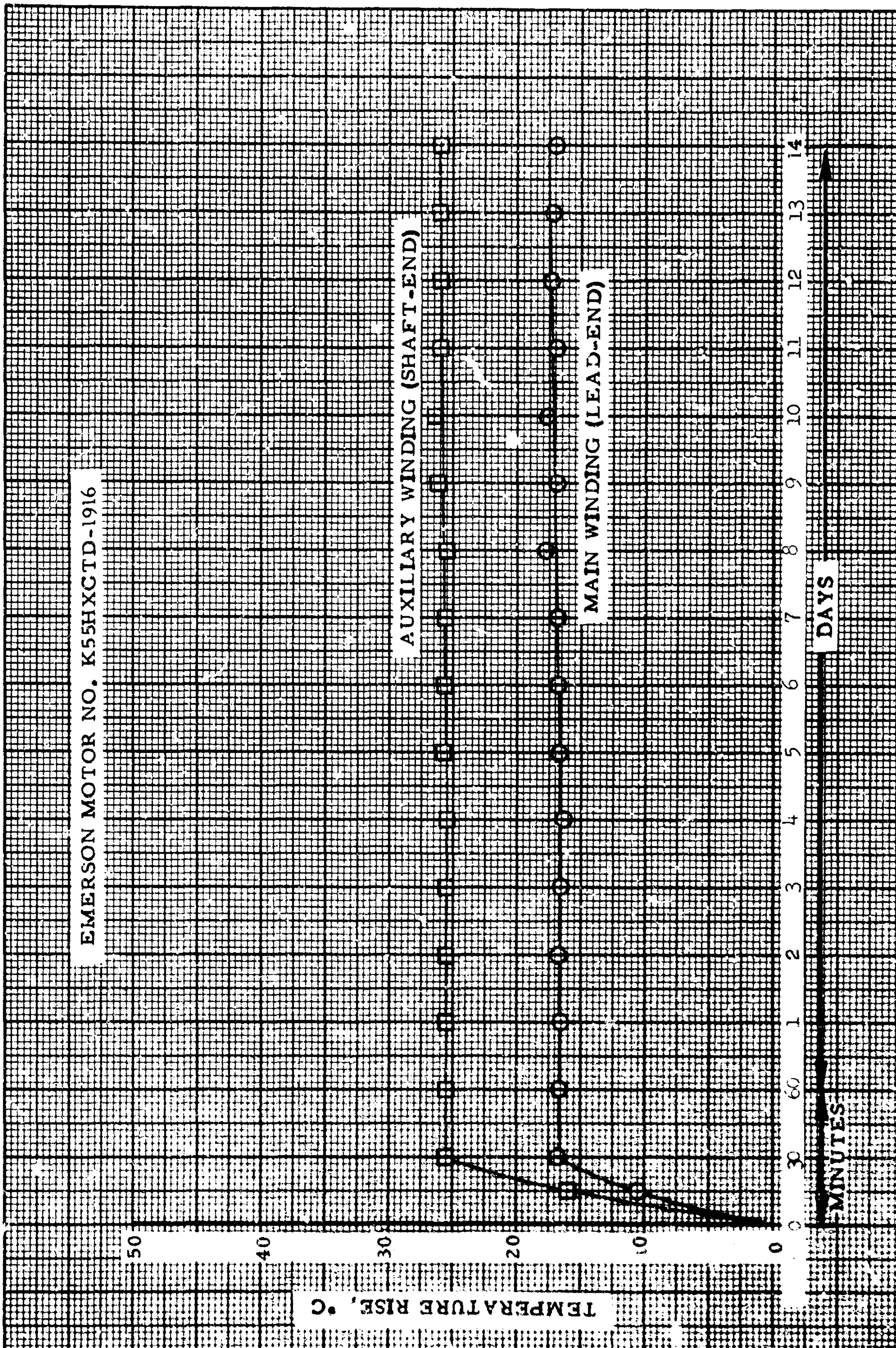

Figure 19 MOTOR WINDING TEMPERATURE RISE

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13. ABSTRACT

Structural, human factors, and motor tests report of a Civil Defense shelter ventilator fabricated according to Specification MIL-V-40645. Since the unit operated without failures the specification was issued 16 August 1965. Minor improvements to this specification are recommended. (U)

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SUMMARY
OF
RESEARCH REPORT

PREPRODUCTION PROTOTYPE PACKAGE VENTILATION KIT, SECOND STRUCTURAL AND HUMAN FACTORS TEST

GARD Report 1278-4.2 August 1965

by

General American Transportation Corporation
General American Research Division
Environmental Research Group
Niles, Illinois

REVIEW NOTICE

This is a summary of a report which has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

MOTOR TEST LABORATORY SET-UP

ABSTRACT

A portable ventilation system, designed for fallout shelters, consisting of a fan assembly and two drive modules was manually operated continuously for two weeks. A previous test had disclosed some mechanical weaknesses that were subsequently changed. The modified unit functioned without any failures; therefore, Specification MIL-V-40645, "Package Ventilation Kit, 20-Inch Fan, Modular Drive (Civil Defense)", was issued 16 August 1965.

Significant conclusions by the American Institutes for Research as to what can reasonably be expected in terms of a person's ability to operate the ventilator are as follows:

1. Roughly 75 per cent of the people tested, aged 14 to 48, can operate the unit for three hours at work-rest schedules of 15 minutes work--7.5 minutes rest, 20 minutes work--10 minutes rest, or 30 minutes work--15 minutes rest at effective temperatures ranging up to 82 degrees Fahrenheit. Under these same conditions, except that the maximum age of the operators was limited to 35 years, 50 per cent are able to operate the unit up to 7 hours.

2. Any instability to operate the unit will manifest itself during the first two hours of operation.

3. Approximately 99 per cent of the people tested who were in the 14 to 27 age group can operate the unit one hour without rest at effective temperatures up to 82 degrees Fahrenheit.

4. Experienced operators can be expected to operate the unit longer than inexperienced team members.

5. Sixty per cent of the males in the age range of 14 to 27 were able to operate the unit continuously for three hours at effective temperatures up to 82 degrees Fahrenheit.

6. Of the work--rest schedules tested (15 minutes work--7.5 minutes rest, 20 minutes work--10 minutes rest, and 20 minutes work--15 minutes rest), no one was significantly better than the others when operating the unit for three hours.

7. The composition of teams operating the unit should be all male whenever possible because mixed teams tend to overwork the male members, and female teams perform less efficiently.

In addition to the structural and human factors test, and prior to the release of Specification MIL-V-40645, the motor was tested (see opposite page), to determine if the motor winding temperature rise exceeded that allowable when operated at elevations up to 5500 feet. The maximum measured temperature rise of the motor windings is 26.5°C when running at 1/3 brake horsepower. The allowable temperature rise is 56°C; therefore, this motor meets the National Electrical Manufacturers Association (NEMA) operating temperature standards when operated at ambient conditions less than 40°C (104°F). This motor also meets the Underwriters Laboratories requirements for approval.